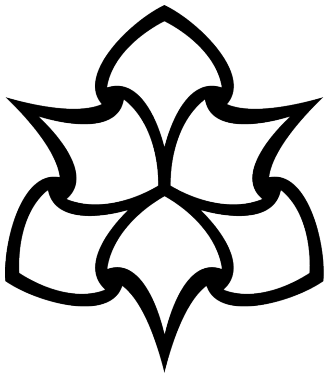


Advances in human factors in complex trauma and emergency anaesthesia and their implementation into military and civilian trauma systems

S J MERCER

PhD 2020

Advances in human factors in complex trauma and emergency anaesthesia and their implementation into military and civilian trauma systems

SIMON JUDE MERCER

A thesis submitted in partial fulfilment of the requirements of the Manchester Metropolitan University for the degree of Doctor of Philosophy

Faculty of Health, Psychology and Social Care, Manchester Metropolitan University

2020

Manchester Metropolitan University
PhD by publication
(Route 2)

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Dr Simon Mercer
MBChB MAcadMEd FHEA FRCA MMEd

Associate Medical Director for Medical Education
Liverpool University Hospitals NHS Foundation Trust

Consultant Trauma and Emergency Anaesthetist,
Liverpool University Hospitals NHS Foundation Trust

Associate Head of School, Health Education England - North West School of Anaesthesia

Honorary Senior Clinical Lecturer, Faculty of Health and Life Sciences, University of Liverpool

Honorary Lecturer in Military Anaesthesia Education, National Institute of Academic Anaesthesia

Contents

Acknowledgements

This thesis is a selection of my work on Human Factors in Complex Trauma that began during my career in the Royal Navy and I have continued now as a civilian at Liverpool University Hospitals NHS Foundation Trust

I would firstly like to thank my wife Elizabeth Mercer for all her support allowing me to undertake projects, attend conferences and deploy with the Royal Navy.

I would also like to thank my parents Peter and Ann Mercer for all their help with childcare looking after my two sons Harry and Freddie and giving me the opportunity to train as a doctor.

I am eternally grateful for the support of Colonel Peter F Mahoney CBE L/RAMC during my Military Career in his role as Defence Professor of Anaesthetics.

I would finally like to thank my colleagues who have worked with me to develop ideas and publish our work.

Abstract

The role of human factors in healthcare was introduced into the mainstream medical literature following two important seminal reports, *'To Err is Human'* from the United States and *'An Organisation with A Memory'* from the United Kingdom. This subsequently led to work conducted by the University of Aberdeen into defining the role of non-technical skills in the Operating Theatre for Anaesthetists, Surgeons and Scrub Practitioners.

This thesis is an overview of work that I have undertaken in both Military and Civilian settings exploring and defining the importance of human factors in the management of complex trauma and emergency anaesthesia. I have undertaken original research investigating the barriers that exist to challenging seniors and have created guidelines for the management of non-iatrogenic airway injuries. This thesis also discusses a novel project that I have been involved in, the development of the 'Trauma WHO', which is a simple checklist designed to improve patient safety during their pathway in complex trauma. I will describe how this was developed, tested in a field hospital in Afghanistan and is now embedded into military practice and some civilian centres.

This thesis also describes further knowledge assimilation in the form of two published peer reviewed systematic reviews exploring the importance of human factors in the emergency department and operating theatre and the management of non-iatrogenic trauma to the airway. Additionally, I have selected five papers for inclusion that demonstrate a translation of knowledge into different trauma arenas where the importance of human factors is essential and now embedded.

The implications of this thesis are that advances in human factors in complex trauma and emergency anaesthesia that were originally developed in the military setting have now been refined and adopted into certain areas of the NHS. The impact of these advances in guidelines for the management of penetrating airway injuries, streamlining communication and flattening hierarchies by awareness of barriers to challenge have been recently witnessed in the expert and successful management of seriously injured patients. Further work to promote these advances is still required to encourage further adoption in other major trauma centres in England.

Aims of the Thesis

Trauma is now firmly at the forefront of NHS England's clinical agenda with an increasing rise in penetrating injuries in London (1) and a recently reported reduction in mortality following the reorganization of trauma services since 2012 (2). This favourable outlook has not always been the case as described in a seminal report published by the National Confidential Enquiry into Patient Outcome and Death in 2007 which was heavily critical of the provision for patients involved in complex trauma (3). Lessons learnt from two recent conflicts in Iraq and Afghanistan (4,5) have slowly been embedded into the National Health Service with the creation of Regional Major Trauma Centers supported by local Trauma Units (6) and an impressive collection of training packages (7,8).

I have been a Medical Officer in the Royal Navy for over 20 years (1998-2018) and deployed to Iraq and Afghanistan as part of the Trauma Team in the Defence Medical Services Role 3 Hospitals. I have also developed the trauma team and was responsible for Anaesthesia Education in the Defence Medical Services producing a continuous professional development matrix (9) and Higher Military Module (10), both approved by the Royal College of Anaesthetists. In addition to the development of new surgical (11) and anaesthetist techniques (4) for managing those involved in complex trauma, success was also attributed to the practice of Human Factors in the trauma team in rehearsal prior to deployment (12,13) and the culture of the trauma team whilst on deployment (14,15) leading to a year on year improvement in survival (5) (Figure 1.1).

The aim of this thesis is to demonstrate that I have a systematic acquisition and understanding of a substantial body of knowledge and am at the forefront of an area of professional practice; human factors in complex trauma. This thesis will also describe and demonstrate some of the work that I have undertaken to generate knowledge through original research, synthesis of

knowledge through systematic review and finally the translation of knowledge through the production of expert peer-reviewed articles. The manuscripts I have selected will concentrate on the implementation and use of Human Factors in the Management of Complex Trauma and Emergency Anaesthesia in both military and civilian settings.

My role at Liverpool University Hospitals NHS Foundation Trust is as the Director of Medical Education and the Lead for Simulation. In coordinating education in the regional Major Trauma Centre, I am required to facilitate training for those doctors, nurses and other members of the multi-disciplinary team who rotate through the hospital to ensure they are prepared to deal with complex trauma. Much of the work described in this thesis forms part of this training which predominately occurs using high fidelity simulation (8). Many of the concepts that are discussed are based on tacit knowledge that has been developed over several years of practice by a group of consultant anaesthetists in the Defence Medical Services who have embedded lessons learnt from recent conflicts into the National Health Service.

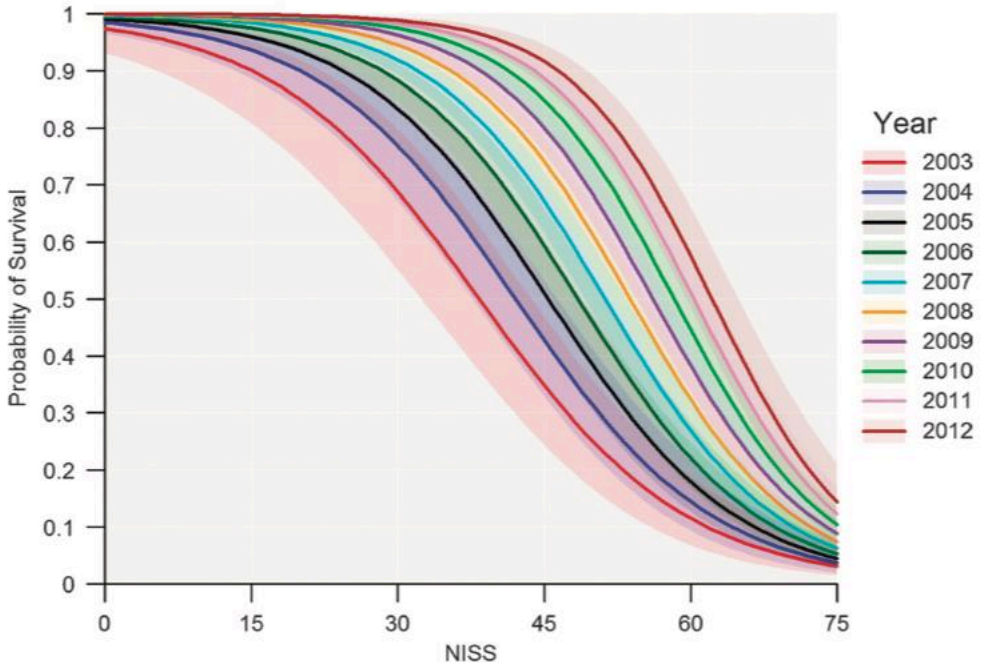


Figure 1.1 Plot of predicted probability of survival by NISS value for each year. Shaded regions indicate the 95% CIs for the predicted values obtained from the logistic regression model. *J Trauma Acute Care Surg*. 2015;78: 1014-1020

The thesis is divided into four sections. The first section is an introduction to human factors and non-technical skills. This is be followed by sections on original research, systematic review and finally on knowledge translation and I will discuss the importance of human factors in the management of complex trauma and emergency Anaesthesia in each section. The original research presented develops the evidence base in the field of human factors and non-technical skills will concentrate of the following peer reviewed publications:

1. Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia Beament T, Mercer SJ *Anaesthesia* 2016; **71**: 1332–1340
2. Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan. Arul S, Pugh H, Mercer SJ, Midwinter M *Annals of The Royal College of Surgeons of England* 2015*;* **97**: 262-268
3. Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries Mercer SJ, Lewis SE, Wilson SJ, Groom P, Mahoney PF. *Journal of the Royal Army Medical Corps* 2010; **156**: S357-362

The systematic review section will consolidate the evidence base in human factors and emergency anaesthesia and the management of non-iatrogenic airway injury and will concentrate on the following peer reviewed publications:

4. Human Factors in Preventing Complications in Anaesthesia Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. *Anaesthesia* 2018; **73(S1)**: 12-24
5. A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma. Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P *British Journal of Anaesthesia* 2016: **117 (S1)**: i49–i59

Finally, expert knowledge translation and synthesis will be considered in the following peer-reviewed published articles to enable communication of the evidence base to members of the multi-disciplinary trauma team working in the Defence Medical Services and National Health Service. These papers have been selected to describe a flavour of human factors in complex trauma in several different environments from the mature field hospital to a remote deployed unit at sea.

6. Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma Mercer SJ, Arul S, Pugh H, Midwinter MJ *Journal of the Royal Army Medical Corps* 2014; **160**: 105-108
7. Human Factors in Trauma Mercer SJ, Tarmey N, Park C *BJA Education* 2015; **15**: 231-236
8. Human Factors on Contingency Operations Mercer SJ, Khan M, Scott T, Matthews J, Henning D, Stapley S *Journal of the Royal Army Medical Corps* 2017: **163**; 78-83
9. Followership in Complex Trauma Fadden S, Mercer SJ. *Trauma.* 2019; **21**: 6-13
10. Human Factors in Complex Airway Gleeson S, Groom P, Mercer SJ *British Journal of Anaesthesia Education* 2016; **16**: 191-197

Throughout this thesis, the Vancouver referencing system will be utilised in preference to MMU Harvard; given that it is this referencing system that is used predominantly in the medical literature and is in keeping with the publications included.

Section 1
Introduction to Human Factors and Non-Technical Skills

This introduction section sets out to define several of the key concepts that will be discussed later in the thesis.

1.1 What are Human Factors?

There are several recognized definitions of Human Factors in the Medical Literature. These are listed at the start of this thesis to allow further explanation in subsequent chapters. One of the leading medical organizations concerning human factors is the Clinical Human Factors Group (https://chfg.org) founded by Martin Bromley OBE, defining Human Factors as *'enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture and organisation on human behaviour and abilities and application of that knowledge in clinical settings'* (16). Work undertaken by Aberdeen University has led to another definition; *'the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance'* (17). A more simplistic definition has recently been described by Moneypenny in the *British Journal of Anaesthesia* as *'the science of improving human performance and well-being, by examining all the effectors of human performance'*(18).

Ergonomics concentrates on designing the workplace and the equipment in it, taking into account the limitations of human performance. The Health and Safety Executive have suggested the definition *'the environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety'* (19). These definitions will be expanded on in terms of the complex trauma team during the thesis.

1.2 History and evolution of Human Factors in Health Care

Many of the principles of Human Factors have been adopted from earlier work by the airline industry, nuclear power stations, the railway and recently formula one motor racing. The National Aeronautics and Space Administration (NASA) described that 70% of errors in its organisation were due to specific Human Factors such as failed interpersonal communication, decision-making, and leadership (20). The development of 'the black box' (flight data recording system) permitted the analysis of key conversations on the flight deck during critical incidents and subsequently detailed examination of the behaviours of the flight crew (21).

Human Factors in Healthcare were really brought to the forefront by the now seminal report *'To Err is Human'* by the Institute of Medicine in the United States (22). This report claimed that up to 98,000 patients died annually due to mistakes in the healthcare system. This report was preceded by UK lead publication *'An Organisation With A Memory'* (23) written by Sir Liam Donaldson the then Chief Medical Officer for England who commented that '*To err is human, to cover up is unforgivable, and to fail to learn is inexcusable'* (24). Recently, The Fourth National Audit Project of the Royal College of Anaesthetists (NAP4) examined major complications in airway management and concluded that poor human factors could have contributed to 40% of the cases reported. In 25% of these cases, inadequate human factors were felt to be a major contributor to a poor outcome (25).

Human Factors were further highlighted by a series of high-profile medical errors, many reported in the press and medical literature. Examples of these include the teenager Wayne Jowett who was in remission from leukaemia but died when he was administered vincristine intrathecally (drug administration into the cerebrospinal fluid) instead of the correct intravenous route (26). The Luer-lock connection on the syringe had enabled the syringe with

the vincristine in it to be attached to the spinal needle and removed the final safeguard thus creating a serious latent error. Another patient, Gordon Reeves had the wrong kidney removed and subsequently died (27). A review of the incident indicated that a medical student present actually knew that the wrong side was being operated on but was ignored by senior colleagues. In addition to this an x-ray in the operating theatre was displayed the wrong way around, also confusing the surgeons and setting up a catalogue of errors. Clinicians in the anaesthetic community are very familiar now with the tragic death of Elaine Bromley(28) who died following a catastrophic breakdown of many Human Factors in the anaesthetic room. In this case a national guideline on the management of unanticipated difficult intubation (29) was not followed and instead of an emergency surgical airway being performed, the anaesthetists persisted with continued attempts at intubation and the patient remained in a hypoxic state for up to 20 minutes.

In 2013, A Concordat from the National Quality Board was published entitled *'Human Factors in Healthcare'* and signed by several national organisations such as NHS England and the General Medical Council to wider promote human factors into clinical practice (30). It is hoped that this document and the renewed political interest resulting from key reports following recent scandals such as in Mid Staffordshire NHS Foundation Trust (31) will encourage the implementation of Human Factors into mainstream clinical practice.

1.3 Non-Technical Skills

Non-technical skills are also described as 'crew resource management' (airline industry), 'crisis resource management' (by Gaba (32)) and 'team resource management'. Much of the work in this field is described by Rall & Gaba (33) (Table 1.1) and Fletcher and Colleagues in

the Anaesthetists Non-Technical Skills Framework (34) (Table 1.2). Schemes have also been developed for Surgeons (35) and Operating Theatre Scrub Nurses (36). Carthey reported that high performing surgeons demonstrated non-technical skills as an integral part of their surgical expertise, and these attributes were thought to play an equally significant role as technical skills (37). In a paper published by the Health Foundation, Professor Rhona Flin described that the following non-technical skills are typically required in clinical settings: situational awareness, decision making and problem solving, leadership, teamwork, communication and managing stress and fatigue. Human factors are also very important in the critical care environment, where patients have life-threatening illness, diagnostic uncertainties, and the potential for rapidly changing medical conditions, and are managed along variable treatment pathways (38). Patient care is carried out over a 24-hour period involving multiple team transitions and moves to different areas of the hospital, which can result in lapses and discontinuities in communication (38). The importance of non-technical skills in the management of patients with complex trauma will be discussed during this thesis.

Table 1.1 Crew Resource Management Key Principles taken from reference (33). Know the environment.

- Anticipate and plan.
- Call for help early.
- Exercise leadership and followership.
- Distribute the workload.
- Mobilize all available resources.
- Communicate effectively.
- Use all available information.
- Prevent and manage fixation errors.
- Cross (double) check.
- Use cognitive aids.
- Re-evaluate repeatedly.
- Use good teamwork.
- Allocate attention wisely.
- Set priorities dynamically.

Table 1.2 The Anaesthetists Non-Technical Skills Framework consists of four categories all containing specific elements (34)

Task management • Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilising resources Team working • Coordinating activities with team members • Exchanging information. • Using authority and assertiveness • Assessing capabilities Situation awareness • Gathering Information • Recognising and understanding • Anticipating and planning Decision making • Identifying options • Balancing risks and selecting options • Re-evaluating

1.3.1. Teamwork

I have listed teamwork as the first of the non-technical skills as this thesis will concentrate on the complex trauma team and how they work together to assess and manage a severely injured patient. A Team is defined as *'a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal, who have each been assigned specific roles or functions to perform, and who have a limited life-span membership'* (39). Another definition being *'a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable'* (40). The complex trauma team and its function are described later in the thesis in section 1.4.1.

1.3.2. Communication

Communication is of particular importance in healthcare. A study by Gawande and colleagues found poor communication to be a causal factor in 43% of errors reported by surgeons at three American teaching hospitals (41). Communication is the ability to impart critical information without the potential for misinterpretation or misunderstanding, irrespective of the situation or the professional diversity of the surrounding team. During this thesis I will describe a communication tool to use in complex trauma that was devised, tested and published in the medical literature (42).

1.3.3. Leadership

One definition of a leader is '*a person whose ideas and actions influence the thought and the behaviour of others'* (17). This thesis will focus on the team leader in the complex trauma team and describe original research that I performed to investigate what drives junior members of the team to challenge (or not challenge) the leader. I will describe the role of the Trauma Team Leader (TTL) who has been described to have a job similar to that of the conductor of an orchestra (15) with multiple team members all working on a severely injured patient and numerous others supporting the resuscitation. The process of leading the trauma team has also been described as '*driving the ship*' but essentially means that the role of the TTL is *'hands off'* maintaining a complete overview of what could potentially be a rapidly changing situation. Figure 1.2 is a photograph taken of the complex trauma team in Afghanistan and Figure 1.3 is a recreation of the trauma team using models. As can be seen in both, the trauma team leader maintains this 'hands off' stance by standing at the end of the bed enabling communication with the whole team and visualisations of all aspects of the trauma call as it unfolds. During the management of a patient with an anticipated difficult airway, the team leader has the following roles; formulating the airway management plan(s) and communicating this to the team, so they are all *'on the same page'*, allocating roles within the team and identifying any limitations in skill mix. The team leader must also maintain situation awareness

and not becoming task fixated while for example the airway is being secured and defining the trigger points for moving from Plan A to B (and subsequent plans) if required.

Figure 1.2. Position of the Trauma Team Leader during a Trauma Call. (Photo courtesy of Dr Mark de Rond)

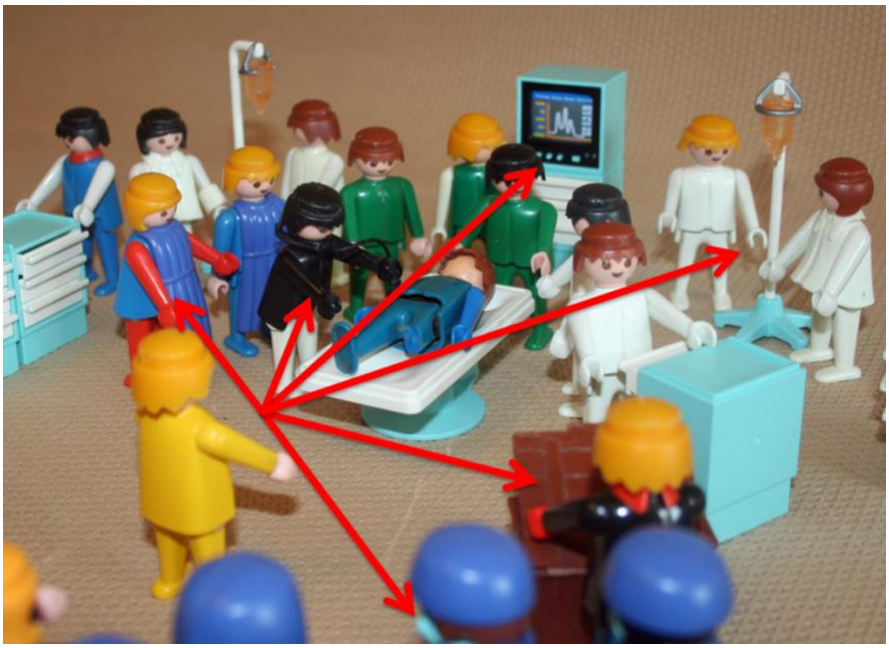


Figure 1.3. Position of the Trauma Team Leader during a Trauma Call to maintain Situational Awareness.

1.3.4 Situation Awareness

This concept describes *'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future'* (43). There are three stages that have been described; gathering information, interpreting the information and anticipating future states. These stages are described in terms of the trauma team in Figure 1.4 Strategies to maintain situation awareness have been suggested, including routines for scanning vital signs and instrument functions (44).

1.3.5 Followership

There are several definitions of the term followership; '*the active engagement of followers in helping the group achieve its goals'* (45), *'people having a shared vision of a common goal or future state, and what needs to be done to reach it'* (46) and *'the ability to effectively follow the directives and support the efforts of a leader to maximize a structured organization'* (47). A follower is also defined as anyone not acting in the position of leader and responding to organizational actions; a person who is active rather than passive (48). During this thesis I will describe the importance of followership in the complex trauma team with reference to a particular article (included as Paper 9) that I have published in *Trauma* (49).

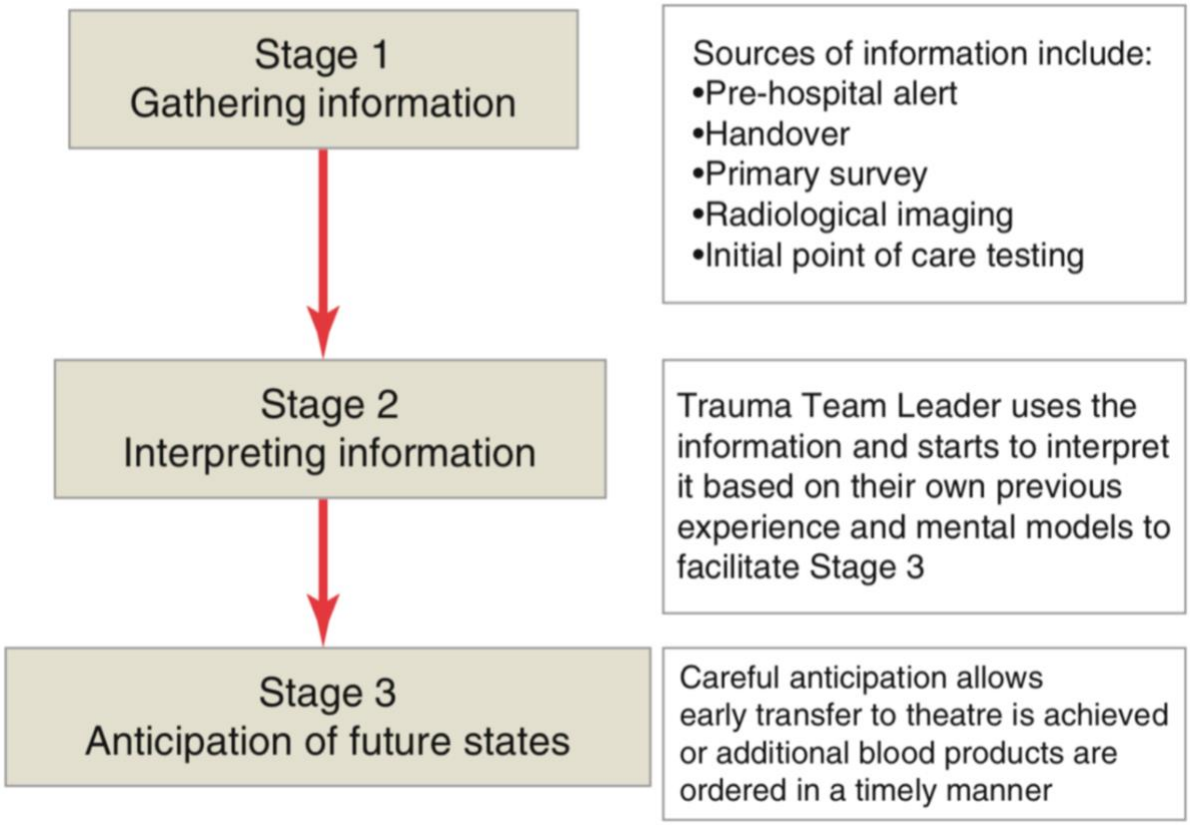


Figure 1.4. The Three Stages of Situational Awareness in a Trauma Setting

1.4 History and Evolution of Trauma Care in England since 2009

Trauma remains a leading cause of death worldwide (50) and is the most frequent cause of death in 15-44 year olds in England and Wales (51) (Figure 1.5). Each year, more than 20,000 patients sustain major trauma, defined by an Injury Severity Score (ISS) (52) of >15 (53)), of which nearly 5000 will suffer life-threatening haemorrhage and an estimated 1,550 will die as a result of bleeding (54). The most common preventable cause of death being from exsanguination due to uncontrollable haemorrhage (55). In November 2007 the National Confidential Enquiry into Patient Outcome and Death published a report which concluded that almost 60% of the patients reviewed received a standard of care that was less than good practice (3). This was the first report that really highlighted the problems with the trauma system in England and was then followed in 2010 by a report from the National Audit Office. This estimated that the annual lost economic output as a result of major trauma was between

£3.3 billion and £3.7 billion (56). The economic burden to the population is considered in this context as if a patient with complex injuries receives timely and optimal care initially by an expert team and then undergoes successful rehabilitation then they could potentially return to work and continue to contribute financially to society. Should they remain unable to work due to the burden of their injuries then the cost of their lifelong care would need to be met by the taxpayer.

These reports paved the way for the reorganisation of the trauma services in England and the creation of Regional Major Trauma Centres (57). This coincided with two major conflicts in Iraq and Afghanistan that involved clinicians working in the Defence Medical Services (UK-DMS) and also the National Health Service (NHS). Lessons learnt in the management of complex trauma slowly started to be translated into NHS practice (4). I currently work at Liverpool University Hospitals NHS Foundation Trust (Aintree site) which is a Major Trauma Centre covering the population of Cheshire and Merseyside in the North West of England. I have also served for 20 years in the Royal Navy and deployed to both Iraq (2009) and Afghanistan (2011) and have been responsible for training the trauma team at Aintree (8).

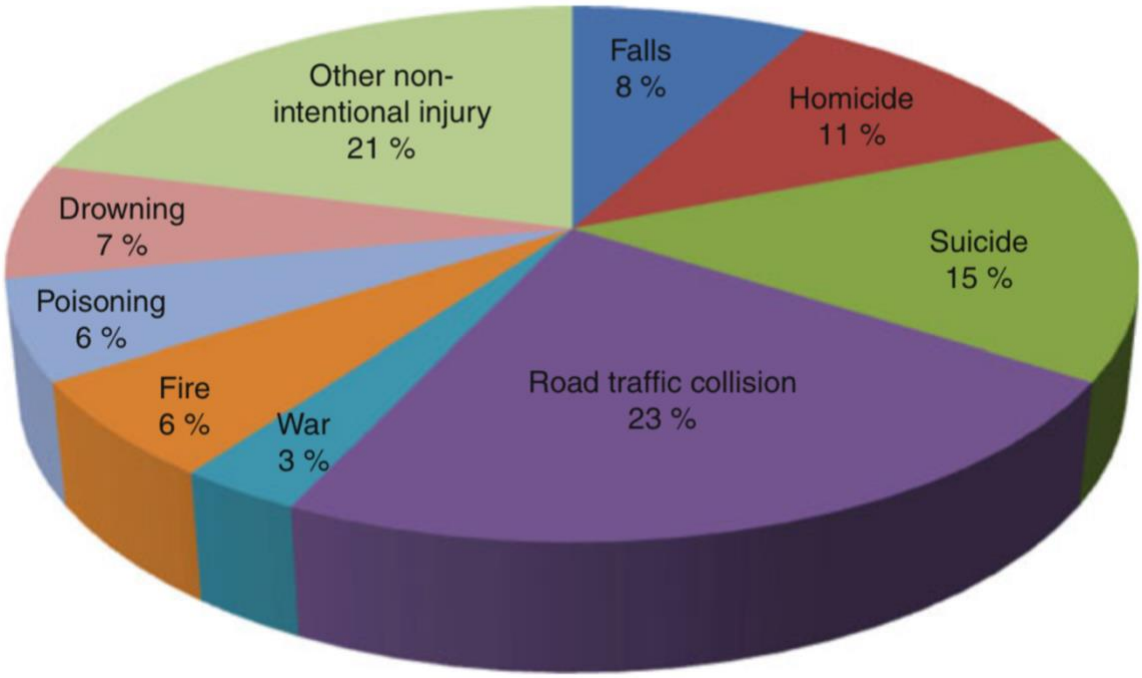


Figure 1.5. Causes of injury deaths worldwide. (Adapted from World Health Organization. Injuries and violence: the facts. Geneva: WHO; 2010)

A systematic review evaluating trauma system performance in the USA (58) found 14 articles and of these, 8 showed improved odds of survival of patients being treated at Major Trauma Centres. Meta-analysis of all published studies found that there was a 15% reduction in mortality in favour of trauma systems. Another study reviewed the outcomes at 18 trauma centres and 51 non-trauma centres in the USA and found a 20% reduction in the risk of death in a trauma centre that increased to 25% when outcome data is extended to 1 year (59). In terms of Trauma now in England, a recent publication by Professor Chris Moran, Trauma Lead for NHS England concluded that of the 110,863 patients reviewed with an Injury Severity Score (ISS) of 9 or more there were no changes in unadjusted mortality, however the analysis of trends in risk adjusted survival for study hospitals showed a 19% increase in the case mix adjusted odds of survival from severe injury (2) (Figures 1.6 and 1.7). This is an early indication that the reorganisation of services to Major Trauma Centres is beneficial to our patients.

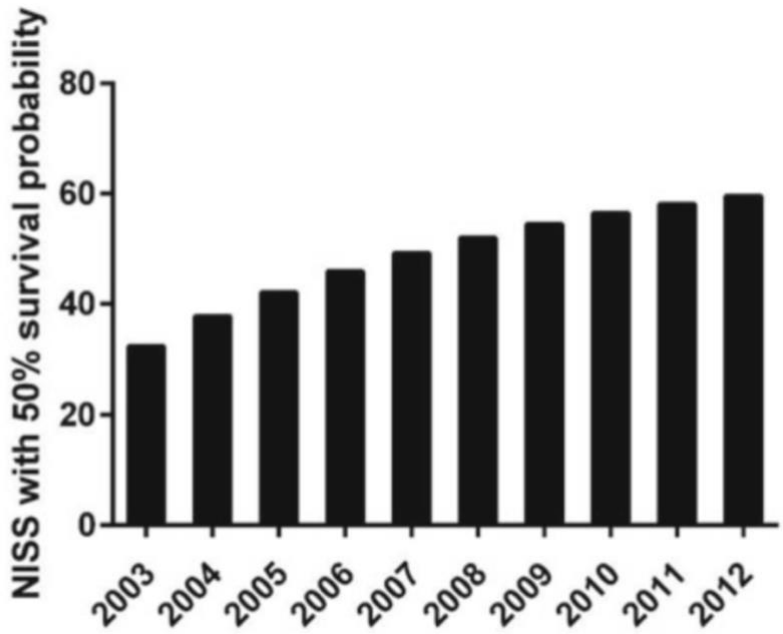


Figure 1.6. New Injury Severity Score (NISS) (60) associated with 50% chance of survival following injury. Data applies to casualties treated by the UK DMS during a period of the Afghanistan conflict (2003–2014) and shows the improvement in survival rates associated with the development of the trauma service. (Figure taken from (61))

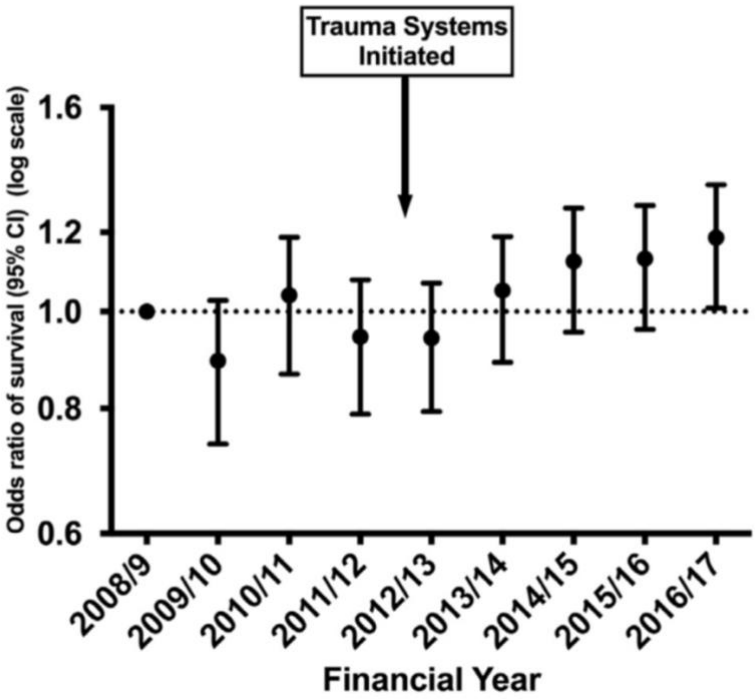


Figure 1.7. Trends in odds of surviving major trauma: April 2008–March 2017. Figure taken from (2)

1.4.1 A Trauma Team

The activation of the trauma team in a Major Trauma Centre is dependent on a pre-determined criterion based on the patient's anatomy, physiology and mechanism of injury, an example of such criteria is described in Table 1.3. Should this criterion be met then a trauma team activation is triggered, and the trauma team is called to the emergency department. A typical NHS trauma team and their roles is described in Table 1.4.

Table 1.3. Trauma team activation criteria (taken from Kings College Hospital London, Major Trauma Service: Information for Members of the Trauma Team) (62)

1	Traumatic event and one of the following: • Oxygen saturation <90% • Systolic arterial pressure < 90 mm Hg • Respiratory rate <9 or >29 bpm • GCS <14
2	Penetrating injury to • Head • Neck • Chest • Abdomen • Pelvis • All gunshot wounds
3	Fractures • Open or depressed skull fractures • Pelvic fracture • Two or more proximal long bone fractures • Flail chest
4	Traumatic amputation
5	Blast or crush injury
6	Major burns • 10% total body surface area but lower threshold in child or elderly • Combination of burns and trauma
7	Road traffic crash • High speed crash (>30 mph) or pedestrian vs. vehicle at >20 mph • Separation of rider and bike • Intrusion into passenger compartment • Ejection from vehicle • Death of another person in the same passenger compartment • Bull's eyed windscreen • 20 min extrication time
8	Falls • Height of >3 m • Paediatrics—consider the age and height of the child in relation to the height fallen
9	Helicopter Emergency Medical Service (HEMS) transfer
10	Drowning/submersion

Table 1.4. The composition and roles of a Complex Trauma Team at a typical Major Trauma Centre in England

Role	Function in the Trauma Team
Team Leader [Emergency Department Consultant]	Allocation of roles to the team Maintaining situational awareness
Primary Survey Doctor [Emergency Department Trainee ST3+]	Conducts the Primary Survey
Anaesthetist [Senior Trainee (ST5+)]	Airway management
Operating Department Practitioner (ODP)	Assisting the Anaesthetist Setting up anaesthesia equipment
Radiographer	Portable x-ray
Orthopaedic Surgeon [ST4+]	Responsible for orthopaedic injuries
General Surgery [ST4+]	Responsible for surgical injuries
Runner [HCA]	Collects blood and blood products from the transfusion laboratory and other equipment as necessary
Emergency Department Nurse [1]	Obtaining intravenous access and blood transfusion
Emergency Department Nurse [2]	Drawing up intravenous medication
Scribe [Senior Nurse]	Accurately recording observations and drug administration

1.4.2 The Trauma Call

This thesis will describe the importance of Human Factors during a trauma call and subsequent transfer of a patient to the operating theatre. I will describe and critically appraise original research that has been performed in an attempt to improve communication during the management of complex trauma (42). I have recently published an article in the *British Medical Journal* (63) describing the process of a typical trauma call in a Major Trauma Centre, the main highlights and timelines are shown on the infographic in Figure 1.8. A complex trauma patient may require Damage Control Resuscitation which is defined as *'a systemic approach to major trauma combining the <c>ABC paradigm (control of catastrophic haemorrhage, airway, bleeding and circulation) with a series of clinical techniques from point of wounding to definitive treatment in order to minimise blood loss, maximise tissue oxygenation and optimise outcome'* (64). A senior clinician as the trauma team leader, allows early decision making in terms of the patient's treatment pathway which could involve transfer to CT Scan, Operating Theatre, Critical Care or the Major Trauma Ward (Figures 1.9 and 1.10 from (4)).

Figure 8 - Taken from reference 63

thebmj Visual summary

Trauma call timeline

This suggested trauma team timeline is based on a combination of guidance from expert opinion and experience of UK emergency departments. It aims to help clinicians familiarise themselves with the basic principles of organising and responding as a trauma team, and the central role of the trauma team leader.

T-15
15 minutes before arrival of patient

Team assembles
Ensure all team members present → Introductions → Allocation of roles

Declare code red?
Inform transfusion laboratory if a "shock pack" is required

Team brief
Team leader briefs the team with information from the pre-hospital alert. Team discusses what they expect to happen

Make ready
- Equipment
- Drugs

Time T
Patient arrives

Initial assessment
Prior to receiving a sterile handover confirm:
- 1 Patent airway
- 2 Central pulse
- 3 No visible active haemorrhage

Patient handover
Pre-hospital handover is received with trauma team silence using "AT-MIST"

A	T	M	I	S	T
Age	Time of injury	Mechanism of injury	Injuries sustained	Signs and symptoms	Treatment given so far

T+0
Immediate actions

Horizontal assessment
Components of the <C>ABCD paradigm and initial investigations (such as chest and pelvic x ray, and blood tests) are carried out by several people at the same time, coordinated by the trauma team leader. This allows the team to have the required clinical information quickly

<C>	A	B	C	D
Control of catastrophic haemorrhage	Airway	Breathing	Circulation	Disability

Initial treatment
- Oxygen — 15 L via non-re-breather mask
- Secure large bore venous or intraosseous access
  To allow rapid administration of blood and blood products

Blood tests
- Full blood count
- Venous blood gas
- Blood group and save
- Urea and electrolytes
- Thromboelastometry (Such as RoTEM)
- Point of care INR testing (If patient is on warfarin)

Example of <C>ABCD systematic approach

<C>	Amputated limb: Apply tourniquet and compression bandage with or without topical haemostatic agents
A	Actual or impending airway compromise: RSI* with cervical spine control
B	Ventilatory failure: RSI* and consider need for chest decompression: needle versus thoracostomy versus chest drain insertion
C	Pelvic fracture suspected: Apply pelvic binder Long bone fractures: Splint and assess peripheral pulses
D	Unconsciousness (GCS 8 or less), unmanageable, combative or severely agitated patient with a head injury: RSI*

T+5
5 minutes after arrival

Review <C>ABCD
Assess whether essential bodily systems are under control

<C>	A	B	C	D
Catastrophic haemorrhage controlled?	Reassess airway and indications for RSI* if not yet performed	Assess ventilation status and effectiveness of chest decompression	Consider whether a massive transfusion is required	Reassess Glasgow coma scale

Consider further treatment
- Chest and pelvic x rays
- Is further Intravenous access needed?
- Ultrasound (FAST† scan) to aid critical decision making

Analgesia
Consider risks and benefits of RSI*. It may be needed for humanitarian reasons, if patient is in very severe pain and an operation is planned very soon

T+15
15 minutes after arrival

Situational update
- Immediate CT scan versus transfer to operating theatre
- Set goals on physiology and blood products
- Ongoing transfusion requirements?

Secondary survey
May be performed if patient does not require time critical interventions

Prepare for transfer
- Reassess splinting and all dressings
- Secure patient and all IV access lines
  Use a vacuum mattress
- Consider use of a pre-departure checklist

T+20–30
20–30 minutes after arrival

Command huddle
Once the initial examination of the patient is complete, a decision on the next steps of treatment is made by senior members of the team. This is then communicated to the whole trauma team

Confirm drugs given so far
- Analgesia
- Tranexamic acid (15 mg/kg)
- Antibiotics
- Tetanus prophylaxis
- Calcium chloride

Inform family
The trauma team leader and a senior nurse (usually the scribe) will talk to the patient's family to explain the situation

Transfer
If a CT scan has been performed elsewhere, consider priority transfer to:
- Operation theatre
- Critical care
- Interventional radiology
- Trauma ward

* RSI = Rapid sequence induction of anaesthesia

† FAST = Focused Assessment with Sonography for Trauma

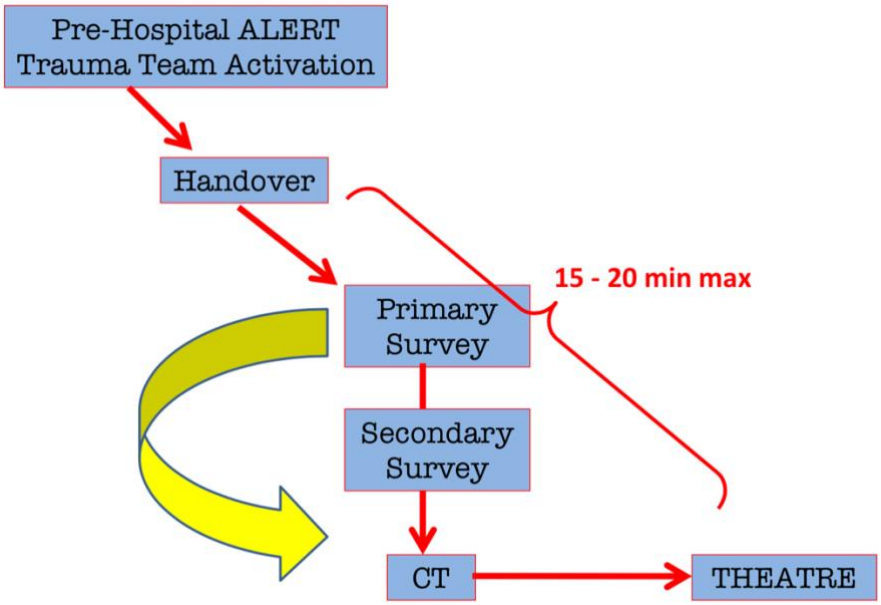


Figure 1.9. Patient Pathway leading to CT Scan and then Operating Theatre. Figure taken from (4)

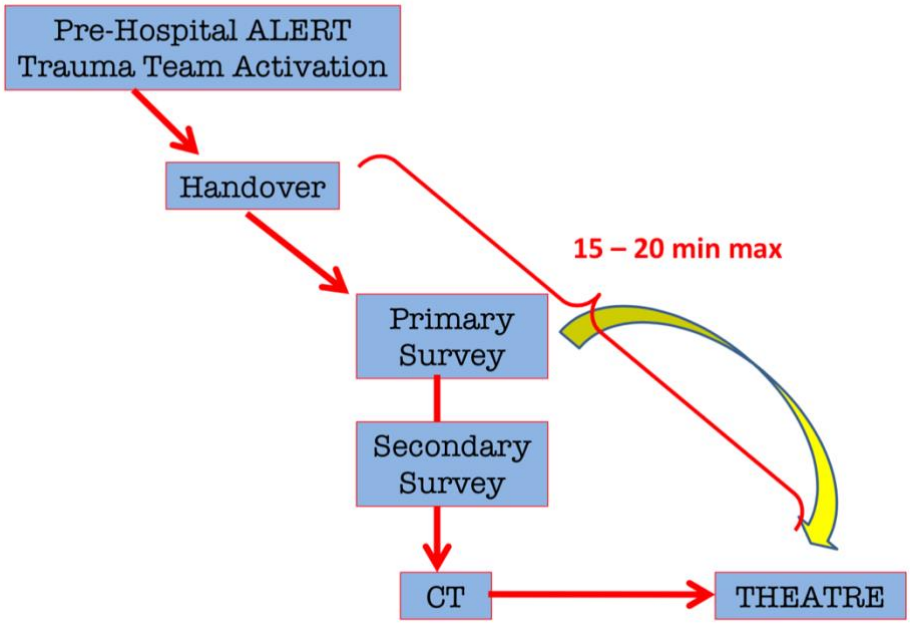


Figure 1.10. Patient Pathway leading to direct transfer to the Operating Theatre. Figure taken from (4)

1.5 Overview of the thesis

This thesis will describe the recent advances in human factors in complex trauma and emergency anaesthesia and then how they have been implemented into military and civilian trauma systems. Sections on original research, systematic review and knowledge translation will allow me the opportunity to present my published work and demonstrate how original knowledge and knowledge assembled from systematic review has been introduced and implemented successfully into mature trauma systems.

Three original research manuscripts will examine the barriers to junior anaesthetists challenging the decisions of senior anaesthetists, the use of a communication tool *'The Trauma WHO'* [14] to enhance communication amongst the trauma team and the creation of guidelines for the management of casualties with penetrating airway injuries. Two systematic reviews are presented that appraise and summarise the current literature around human factors in complex trauma and emergency anaesthesia and also in the management of penetrating neck trauma. Finally, there are five articles that have been selected to demonstrate the skill of knowledge translation all relating to different clinical situations where human factors in trauma are vital to the functioning of the complex trauma team. It is this translation of knowledge that I perform on a daily basis training teams in theatre and in the high-fidelity simulation centre attached to my hospital.

The ten articles selected, described and critically appraised will allow me to describe how original knowledge and knowledge summarised in the systematic reviews are vital to the management of complex trauma patients in different situations and also demonstrate an ability to translate the findings of more complex articles and guidelines in a 'digestible' format that can be read by busy practitioners to keep updated on good practice in trauma care.

Section 2

Original Research

2.1 Introduction

My publications are listed in chronological order in Appendix 1. I have selected the following three manuscripts to demonstrate my contribution to original research in the field of Human Factors in Complex Trauma and these will be described and critically appraised in this chapter of the thesis.

- Beament T, **Mercer SJ**. Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia. *Anaesthesia* 2016; **71**: 1332–1340

- Arul S, Pugh H, **Mercer SJ**, Midwinter M Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan. *Annals of The Royal College of Surgeons of England* 2015*;* **97**: 262-268

- **Mercer SJ**, Lewis SE, Wilson SJ, Groom P, Mahoney PF. Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries. *Journal of the Royal Army Medical Corps* 2010; **156**: S357-362

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

3. Title of Research Output

Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia Beament T, Mercer SJ Anaesthesia 2016; 71: 1332–1340

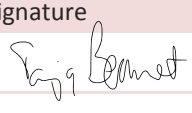
4. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer - 40% - Inital idea for project, participation in simulation scenarios and in focus groups, contributed to thematic analysis, 1st draft of article and subsequent revisions
T Beament (60%)

5. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
T Beament		tbeament@gmail.com

6. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature: Date:

(Director of Studies/Advisor)

7. Signature of Faculty Research Degrees Administrator

Signature: Date:

(Faculty Research Degrees Administrator)

Anaesthesia 2016, 71, 1332–1340 doi:10.1111/anae.13546

Original Article

Speak up! Barriers to challenging erroneous decisions of seniors in anaesthesia

T. Beament[1] and S. J. Mercer[2,3]

1 Anaesthetist, Alb Fils Kliniken, Goeppingen, Germany
2 Consultant Anaesthetist, Aintree University Hospital NHS Foundation Trust, 3 Director, Centre for Simulation and Patient Safety, Liverpool, UK

Summary

'Speaking up' or the ability to effectively challenge erroneous decisions is essential to preventing harm. This mixed-methods study in two parts explores the concept of 'barriers to challenging seniors' for anaesthetic trainees, and proposes a conceptual framework. Using a fully immersive simulation scenario with unanticipated airway difficulty, we investigated how junior anaesthetists (one to two years of training) challenged a scripted error. We also conducted focus groups with senior trainees (three to seven years of training) and undertook a 'thematic network analysis' of responses. Junior anaesthetic trainees challenged erroneous decisions effectively, but trainees with an additional year of experience challenged more quickly and effectively, combining 'crisp-advocacy-inquiry challenge' with 'non-verbal cues'. Focus group analysis conceptualised a 'barrier network' with three main themes: concerns around relationships; decision-making; and risk/cost–benefit. Emotional maturity is an important protective layer around decisions to challenge. Despite significant multifactorial barriers, systematic training in effective 'speaking up' could improve the confidence and ability of juniors to challenge erroneous decisions.

Correspondence to: T. Beament
Email: tbeament@gmail.com
Accepted: 3 May 2016
Keywords: failed airway management; hierarchy; human factors; patient safety; speaking up

Introduction

Analysis of the tragic death of Elaine Bromiley highlighted a breakdown of several important non-technical skills [1], including the failure to challenge senior consultants who persisted with inappropriate airway management. A recent publication from the Difficult Airway Society on how to manage unexpected difficult tracheal intubation [2] suggested limiting the number of intubation attempts, with a direction to perform emergency surgical cricothyroidotomy if conventional ventilation is impossible. In another high profile case, a patient had the wrong kidney removed and subsequently died, despite a junior member of the team knowing that the healthy kidney was being operated on [3].

Failure to challenge erroneous decisions contributes to patient morbidity and mortality [4]. Team members with the interpersonal skills to challenge the decisions of their leaders without contributing to a defensive or risk-adverse culture are referred to as responsible followers [5], while a reluctance to speak up threatens patient safety [6]. For the purposes of this article, we define 'speaking up' as communicating other team members' doubts, differing opinions or

potential problems about decision or course of action in medical care. Challenging other colleagues' views involves taking risks on the part of those who speak up, especially in hierarchical systems such as healthcare, where the terms 'juniors' (doctors in training) and 'seniors' (consultants) infer this divide. In order to improve training on this subject, it is vital to clearly identify effective interpersonal skills and possible barriers to challenging seniors [7].

Summarising all known 'barriers to challenging' from the recent literature (Table 1), it is evident that, despite ample research, barriers to effective communication in medical emergencies are complex, contradictory and still poorly understood. Previous work suggests that using simulation to include deliberate erroneous decisions during training can uncover failures to speak up and promote appropriate leadership challenges [4, 8–10]. Recent research also suggests that doctors can, in a similar way to the aviation industry, train for and assess 'surprise and startle' events [11], and that effective 'speaking up' can improve patient safety [12].

Methods

Research and development institutional research ethics approval was granted for this study by Aintree University Hospital NHS Foundation Trust Research and Development Department.

For the first part of the study, a qualitative approach using focus group verbatim transcriptions of senior anaesthetic trainees (three to seven years of experience, ST3-7) was used. A total of 12 of all invited ST3-7 trainees in the Mersey Deanery participated in four facilitated focus group sessions to discuss barriers to challenging consultants in their own and other specialties involved with peri-operative care. Each session lasted approximately 30 min (two to five participants in each group).

Initial questions were standardised using a set of predetermined open questions to initiate and deepen discussions between participants and their experiences of challenging or failure to challenge consultants. Participants were encouraged to exchange anecdotes, clarify their views and remark on each other's experiences. Field notes were taken, and all focus group sessions were audio-recorded, transcribed verbatim and de-identified.

Table 1 Summary of previously identified barriers to challenging [4, 9, 10, 12–16].

Authors	Barrier themes identified
Belyanski, et al. [4]	• Poor intra-operative communication between seniors (attendings) and juniors (residents)
Bould, et al. [9]	• Hierarchy in operating theatres • (Weak) position of individual within the perioperative team • Negative effect (challenge detrimental) of challenging on learner, patient, learning
Friedmann, et al. [10]	• Behaviour of seniors (inclusive-friendly versus exclusive-hostile); no barrier for challenging • Lack of formal training
Okayuma, et al. [12]	• Motivation and clinical context (perception of low risk to patient) • General contextual factors (teamwork and individual's relationship within team, attitude of senior) • Individual factors (lack of knowledge or confidence, poor communication skills) • The perceived safety of speaking up (fear of reprisal, concerns of appearing incompetent, avoiding conflict) • The perceived efficacy of speaking up (prediction that nothing will be done)

Kobayashi, et al. [13]	• Ethnicity/nationality and linked hierarchical social structures: no difference in self-reported threshold to challenge
	• Differences in beliefs regarding factors thought to affect challenging
	  ○ Penalty, repercussion
	  ○ Social acceptance, rejection
	  ○ Knowledge, experience, understanding
	  ○ Image, self-worth
	  ○ Teamwork, professionalism, hierarchy
	  ○ Communication skills
	  ○ Relationship, personality

Pian-Smith, et al. [14]	• Assumed hierarchy • Fear of embarrassment of self or others • Concern over being misjudged, fear of being wrong • Fear of retribution • Jeopardising an ongoing relationship • Natural avoidance of conflict • Concern for reputation
Sydor, et al. [15]	• No effect of operating room hierarchy on challenging behaviour • Lack of training in effective challenging techniques
Weiss, et al. [16]	Interindividual factors such as: • Lack of agency (assertiveness, persistence, independence) • Presence of communion (helpfulness, friendliness, sociability)

Data were analysed using a thematic network analysis of known barriers and new, emerging barriers, leading to the formulation of 'barrier clusters'. Subsequent qualitative analysis of barriers to challenging seniors used an iterative process of coding according to a set of known barriers from previous literature (Table 1), and also allowed for emerging, previously unidentified themes in an exploratory approach informed by grounded theory.

Manual coding of transcripts through a constant comparative process between transcripts, and similar phrases from previously identified known barriers were used. In line with a thematic network [17], we noted keywords next to basic (first level) themes, and gradually grouped them into three common organising (second level) themes to explain the complexity by which these personal, organisational and situational factors interconnect and influence the global theme of perceived barriers to challenging erroneous decisions by anaesthetic trainees. To increase the validity and reliability of our findings, we undertook a process of inter-rater conformability, whereby both authors independently coded the first transcript independently. We then engaged in a repeated coding process that led to agreement on most of the codes.

For the second part of the study, we undertook a quantitative analysis of a simulated high-fidelity airway crisis, whereby a confederate consultant anaesthetist failed to intubate a patient, and junior anaesthetic trainees (first two years of training, CT1/CT2) were expected to challenge decisions that were clearly wrong. This was combined with a qualitative analysis of barriers to challenging that were expressed and identified during the debrief session.

We recruited and obtained written consent from 13 junior anaesthetic trainees within their first (n = 6) and second (n = 7) years of anaesthesia training in Merseyside, UK. They were asked to complete a background questionnaire (age, sex, grade, years experience, simulation experience, ethnicity and medical school) before participation. We explained that they were to participate in a videoed, standardised and scripted fully-immersive failed intubation simulation.

After a short briefing, the trainee joined the 'theatre team', which consisted of actors playing the roles of consultant anaesthetist, operating department practitioner (ODP) and surgical consultant, just before completion of the first part of the World Health Organization (WHO) surgical checklist. A SimMan (Laerdal, Orpington, Kent) 3-G wireless simulator was used to simulate a patient who was just about to undergo emergency abdominal aortic aneurysm repair surgery. The trainee anaesthetist was asked to inject the drugs for induction of anaesthesia and neuromuscular blockade. The confederate faculty consultant anaesthetist was deliberately unable to intubate the patient simulator, and then became task-fixated on intubation, failing to oxygenate and ventilate despite oxygen desaturation. The scenario was controlled by another faculty member, who adapted patient observations to a predetermined script of worsening oxygen saturations. The candidate was expected to constructively challenge further intubation attempts, and suggest a rescue ventilation technique to oxygenate the simulated patient. If the candidate failed to challenge appropriately, the ODP suggested using a supraglottic airway device after a pre-agreed duration of hypoxia.

Trainees were debriefed immediately following the simulations using video playback from their respective scenarios. A method called 'thinking aloud' [18] was used, whereby they were asked to comment on and describe their thinking and actions during video playback, allowing exploration of displayed behaviours, barriers to speaking up and strategies used for challenging. The simulation videos and debrief recordings were de-identified, and main excerpts were transcribed using a mixed-method approach. Key events were quantitatively and qualitatively analysed according to primary outcome measures (Table 2). Challenges were graded according to an adapted 'challenges grading score' (Table 3).

Results

For the focus group discussions, we used a thematic network analysis [17] to identify 22 basic (first level) themes to describe barriers to challenging erroneous decisions. These were further linked into the three main organising (second level) themes of 'relationship concerns', 'decision-making concerns' and 'risk/cost–benefit concerns' to explain the global theme (third level) of 'barriers to challenging erroneous decision in anaesthetic trainees'. Examples of these barriers,

Table 2 Summary of primary outcomes from the fully immersive simulation scenario. Values are mean (SD).

Primary outcome measures	CT1 trainees	CT2 trainees
Time to 1st challenge; s	78.2 (25.3)	68.3 (38.8)
Time to highest grade (CAIC) challenge; s	272.0 (67.8)	172.7 (55.8)
Intubation attempts; n	6.5 (2.3)	5.0 (1.2)
Time to oxygenation ($ETCO_2$); s	346 (69)	262 (62)
Lowest SaO_2; %	64 (7)	70 (8)
Verbal communication	14 (4)	13 (2)
Non-verbal communication	08. (0.8)	3.0 (1.8)
Grade 5 challenges	0.5 (0.8)	3.0 (1.8)
Grade 2 challenges	7 (3)	5 (2)

Table 3 Adapted verbal challenges grading score modified to airway scenario [14].

Type	Score	Example
Say nothing	1	
Say something oblique, obtuse	2	"Really?" "sats are 89%" "no breath sounds/no end-tidal CO_2"
Advocate or inquire	3	"I am concerned about the low sats" OR "Shall I get help/the difficult airway trolley?"
Advocate or inquire repeatedly with initiation of discussion	4	"Can we talk about the low sats?" and/or "I'm & uncomfortable with these low sats" and/or "What else can we do?" and/or "Shall we ventilate the patient?"
Use crisp-advocacy-inquiry	5	"I am concerned about violating the DAS intubation guidelines, you have had four goes now, the patient is deteriorating, you need to bag-mask-ventilate or use a supraglottic airway device to ventilate the patient"

stemming from the coding of the focus group verbatim transcriptions are described in a supplementary online table, and via a thematic network diagram (Fig. 1). We also compared barrier themes from focus group trainees with the barrier themes identified during the simulation debrief. Relationship concerns were the most commonly quoted barriers that prevented challenging (mentioned 77 times during focus group discussions), and encompassed many different aspects such as personality of both seniors and juniors, hierarchical structures in medical culture, ingrained respect for seniors and maintaining or establishing relationships or avoiding conflict within a team. Previously established barriers to challenging, such as sex, age and ethnicity, were not considered important by our trainees. Decision-making concerns were less often cited (19 times) by senior trainees, perhaps due to their advanced stage of training, and hence more experience, knowledge and confidence in their ability. When citing these barriers to challenging, trainees mainly spoke about their junior training level, in which they lacked the appropriate skills to make correct decisions and challenge seniors. Risk assessment concerns (cited 29 times) weighed up whether a challenge was worth the potentially negative effects on either patient safety, relationship with the person to be challenged or oneself. These risk concerns were also influenced by the clarity or ambiguity of the clinical decision to be challenged. Clear black and white situations with a potential life-threatening outcome for the patient would be challenged, whereas for grey, ambiguous situations, speaking up may not be worth the supposed negative consequences of their actions.

A new concept that emerged from analysing the focus group transcripts was the idea that emotional maturity acted as an additional layer, rather like a filter around a trainee's decision to challenge or not to challenge. Senior trainees (seven years of training) reported the experience of weighing up and searching for elegant ways to convince the other party of their concerns, in order to achieve a change in an erroneous decision and avoid a head-on confrontation. They rationalised that 'conflict doesn't achieve much... in some ways keeping silent and stepping away from the problem has also been good in achieving the end outcome.'

Thirteen core trainees (six in their first year of training, four women and two men and seven in their second year of training, three women and four men) completed the simulated airway scenario. Sex, ethnicity and medical school were not found to influence study results and observed behaviour. A summary of the

Figure 1 Thematic network diagram of barriers to challenging seniors.

primary outcomes from the simulation scenario is listed in Table 2. Trainees with an additional year of experience in anaesthesia (second year of training) challenged more quickly and effectively by combining 'crisp-advocacy-inquiry challenge' (CAIC) with 'non-verbal cues' (removing equipment, obstructing consultant).

Comparing CT1 and CT2 trainees, CT2s challenged quicker, allowed fewer intubation attempts, established quicker adequate rescue oxygenation and ventilation and less simulated patient desaturation was observed (Table 2). CT2 Trainees also employed more high-grad.

Low-grade 2 or 3 challenges used by CT1 trainees included repetition of worsening saturations and obscure statements such as 'no CO_2' or 'I can't hear anything', or isolated inquiries such as 'do you want me to do anything?', or advocacy statements like 'we can't intubate, can't ventilate but can't wake the patient up' without eliciting any further discussion. As the simulation situation worsened for every further intubation attempt without oxygenation, the grade and quality of the challenges improved in all candidates, and most (9 of 13 trainees, of which all 7 CT2 but only 2 CT1) candidates reached the maximum grade 5 challenge during the scenario, leading to a rescue ventilation strategy. All CT2 trainees spoke more frequently with a grade 4 or grade 5 CAIC communication style. Of particular interest was the use of effective non-verbal challenges in addition to strong high-grade verbal challenges. Eleven candidates (all seven CT2 trainees on numerous occasions, but only four CT1 trainees) prevented the consultant from further intubation attempts by:

- Obstructing the consultant in further intubation attempts
- Removing the laryngoscope
- Placing the facemask near consultant or onto the manikin or face
- Touching the consultant's shoulder/arm repeatedly to gain their attention
- Raising their hand to indicate the need to 'stop'

These non-verbal cues seemed particularly powerful in gaining the confederate consultant's attention, who acted as if situational awareness had been lost during repeated intubation attempts. To our knowledge, no one has as yet reported on the importance of such non-verbal cues as effective tools to challenge erroneous decisions during medical emergencies. Second-year trainees were particularly accomplished at using non-verbal cues, and it is of interest that one single year more in anaesthetic training seemed to equip trainees with this non-verbal skill.

During the speaking-aloud debrief, simulation candidates unanimously agreed that they knew the confederate consultant had mismanaged the crisis, had not followed the Difficult Airway Society Guidelines [2], and that they were worried for the patient's safety. All trainees underestimated the number of intubation attempts they allowed the consultant to have. Most quoted 4–5 attempts, when in fact the consultant had tried many more times (4–7 attempts with CT2 trainees and 5–11 attempts with CT1), suggesting that they themselves had also lost situational awareness. During the debrief, no candidate was upset or felt deceived by the less than complete information regarding the precise focus of the study.

Barrier themes to challenging the confederate consultant identified during simulation debrief with CT1 and CT2 trainees included: hierarchy; respect for and trust in seniors; fear of retribution or negative evaluation; concern for reputation; communication skills; lack of experience/knowledge/understanding; potential negative impact of challenging on patient safety; and risk assessment in view of ambiguity of situation or decision to be challenged (full details are available on request). Barriers from the simulation debrief matched findings from the thematic code analysis of focus group transcripts, and could be attributed to the three main organising themes of relationship, decision-making and risk/cost–benefit concerns.

Discussion

Recent findings [10] could not clearly link trainees' ability or inability to challenge wrong decisions with the communication pattern displayed by the consultant (friendly/open/inclusive or hostile/strict/exclusive). As we discovered, there are still significant and complex barriers that impair trainees' ability to challenge their seniors (Fig. 1). The main barrier themes to challenging seniors were established in both the focus groups and simulation debrief. They were associated with 'relationship concerns' such as hierarchy and respect for consultant experience and 'decision-making concerns' such as lack of knowledge and own perceived inexperience that could potentially damage their working relationship with said consultant. A new emerging theme was concerns surrounding the 'risk/cost–benefits' of making a challenge. Trainees effectively weighed up the potential consequences for patient harm of challenging or not challenging, versus the potential negative effects on themselves or their relationship with the senior in the context of the clinical situation/decision to be challenged.

The importance of hierarchical organisational factors as a barrier to challenge erroneous decisions can be linked to junior trainees wanting to show clinical independence and avoid seeking help [19]. Situated learning models perceive learning not only as gathering more knowledge and skills but also as the development of a new identity as a member of a particular community of practice [20]. By aspiring to become expert clinicians, juniors may feel under pressure to manage anaesthetic emergencies on their own without asking for help. There is still a misconception, perhaps less so in anaesthesia but nevertheless prevalent in the medical profession, that calling for help is a sign of weakness or failure to cope. Trainees unanimously voiced their awareness of the consultant disregarding the Difficult Airway Society guidelines [2] by attempting tracheal intubation more than three times during emergency intubation. However, trainees also stated that it was acceptable for consultants to 'break the rules' in defined circumstances, but it was perceived that trainees were required to follow them under all circumstances.

Some trainees attributed their reason for not challenging to a lack of confidence [10], which is reflected in both the focus groups and the simulation debrief. Participants described situations whereby they expressed uncertainty about their competency and knowledge, and were unclear whether they should be able to manage a situation rather than ask for help. They also felt they lacked experience to decide if a

decision might be wrong, as juniors thought that consultants 'ought to know better' and that their own role was to follow rather than to lead.

The transition from novice anaesthetist to expert seems to diminish associated feelings of anxiety when being forced to take responsibility and challenge erroneous decisions. Experience, and this is a time-dependent and not just competency-based attribute, is the solution to a more confident challenge, as one candidate expressed: '... when you've got a layer of experience that gives you confidence in your decision-making.'

Figure 2 illustrates the concept of a risk/cost–benefit analysis that goes on in a trainee's mind when considering speaking up, and attempts to display the conceptual connection between clinical ambiguity (grey scenarios vs. black and white scenarios) and the severity of perceived consequences for patient harm.

In a black and white scenario with clear guidelines to follow and a perceived threat to actual severe patient harm, trainees would be more likely to pose a challenge. However, in a grey scenario involving ethical ambiguity or multiple treatment options, whereby certain decisions by a senior would not cause patient harm (even if a better decision was possible), trainees would not speak up unless their relationship with said senior was strong and not scarred with hierarchical power-distance issues or fears of repercussion.

Several studies that researched the influence of hierarchy on speaking up [9, 14, 21] used ambiguous or 'grey' scenarios, whereby ethical considerations and several potential correct decisions were possible, and hence were identified as confounding factors in the willingness of trainees to speaking up [9, 12, 21]. Emergency decision-making is complex, and study design with grey scenarios renders methods even more ambiguous, as the interpretation of participants' actions or inactions could be a result of an ambiguous scenario and may not accurately reflect trainees' ability or inability to challenge.

This research scenario was deliberately chosen to be a clear 'black and white' deviation from emergency airway management, with the confederate consultant disregarding the Difficult Airway Society guidelines [2] and potentially endangering the patient. Black and white scenarios and resulting actions are easier to interpret, but may feel artificial and divorced from real life, as real medical emergencies are anything but 'black and white'.

Overall, the most striking findings were the difference in performance between CT1 and CT2 trainees. Trainees with an additional year of experience (CT2) challenged the consultant more quickly and effectively using appropriate non-verbal cues. This included putting a hand up to obstruct the consultant, and removing the laryngoscope while placing the facemask on the patient in an attempt to prevent further desaturation. This ensured that fewer intubation attempts were made, thereby allowing oxygenation and ventilation to be established more quickly. Of particular note was the more frequent use of high-grade CAIC communication, particularly in combination with clear non-verbal

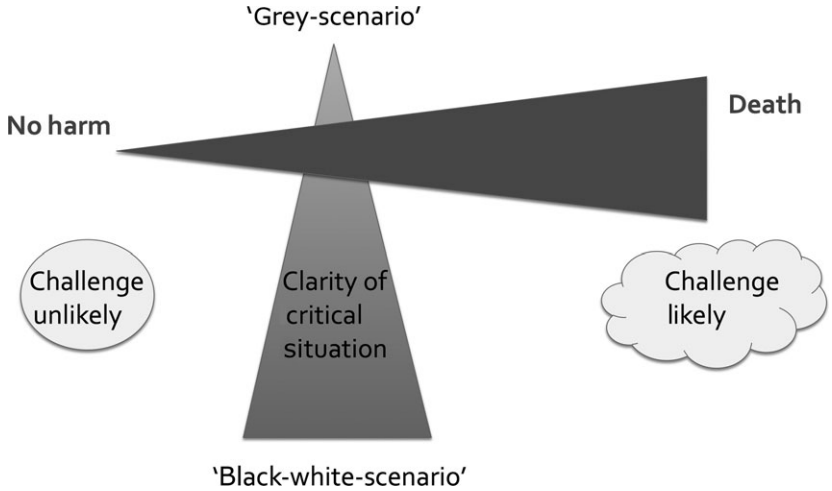


Figure 2 A model of the cost–benefit analysis making a challenge likely or unlikely.

cues. All trainees (CT1 and CT2) initiated an appropriate challenge to prevent the confederate consultant from making further intubation attempts, and ventilated the patient. There was no need for the faculty ODP to rescue the situation and avoid simulated patient death by suggesting alternative strategies for ventilation.

Our results contrast with recent findings, where the quality of Canadian trainees' challenges was assessed as 'mostly poor, . . . isolated inquiry or advocacy statement, . . . no use of crisp advocacy/inquiry and no attempts to take over management of the case' [10]. The inability to challenge authority could not be attributed to superiors' interpersonal communication, but to a lack of conflict management training [10]. This identifies systematic failure rather than failure of individual trainees. Although we support this notion of demanding more formal 'speaking up' training, our findings in the UK differ from those in Canada [10], perhaps through the impact of high profile medical tragedies such as Elaine Bromiley's death [1] and the subsequent work of Martin Bromiley through his Clinical Human Factors Group (CHFG). Additionally, the recent agreement of key NHS organisations, professional institutes and regulators to sign the Concordate for Human Factors in Healthcare [22] brought human factors values and training to the forefront in emergency and especially anaesthetic training in the UK. In our region (Mersey, UK), medical students and junior doctors attend mandatory simulation courses regularly throughout their training. These courses do not specifically train challenging techniques, but trainee doctors get taught communication, teamwork and crisis management from an early stage onwards. The importance of effective communication (open-ended questions, closing of the communication loop, sharing frames of understanding and declaration of the emergency) is also highlighted.

The General Medical Council [23] is clear: doctors have an overriding duty to 'take prompt action if you think that patient safety, dignity or comfort is being compromised'. Hierarchy and conflict will certainly contribute to team tensions and build barriers within a team, but doctors must override this duty to 'speak-up-for-safety'. Training on these issues should not only be targeted towards juniors' ability to speak up, but also for seniors to be receptive to questions and challenges. Seniors must actively contribute to creating a culture where all team members are valued, decision-making is shared, and humiliation or bullying repercussions of conflict are no longer acceptable. Concerns about the lack of high-quality, effective challenges by trainees [9, 10, 15] according to a CAIC principle suggest that learning of such speaking up skills should be included in curriculae to improve patient safety [12]. In our study, we demonstrated that our regional training programmes, although not perfect, did prepare junior anaesthetists to effectively challenge seniors' wrong decisions.

Anaesthesia departments should encourage regular in-situ simulation practice to include the whole multidisciplinary team, so that patient safety is seen as part of the team approach to safety.

In summary, a key finding in our study was the effectiveness of non-verbal cues, which were particularly used by more experienced trainees and which worked synergistically with high-level CAIC to rescue flawed clinical situations and encourage the consultant to change their erroneous actions. We also presented a thematic network model of 'barriers to challenging seniors' (Fig. 1) that combines previously known and newly described themes to advance our current knowledge of the field of barriers to speaking up, and highlighted the importance of emotional maturity as an additional layer or buffer that influences the decision process. Our 'cost/risk–benefit' conceptual model (Fig. 2) may prove useful in understanding the complicated decision-making process underlying 'speaking up' behaviour.

Acknowledgements

We thank Dr Cathy Sherratt, Clinical Education Manager and Programme Leader, Edge Hill University, UK for her help preparing the manuscript, and Mr Mark Murphy, Mr Neil Rimmer, Mr Tim Parr, Mrs Toni Shanahan and Dr Emma Welfare from the Centre for Simulation and Patient Safety, UK for their help in conducting the simulation scenarios.

Competing interests

TB was granted a small research fund by the Society for Education in Anaesthesia (UK) to pay for

professional transcription services. No competing interests are declared.

References

1. Bromiley M. Have you ever made a mistake? *Royal College of Anaesthesia Bulletin* 2008; **48**: 2442–45.
2. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society guidelines for management of unanticipated difficult intubation in adults. *British Journal of Anaesthesia* 2015; **115**: 827–48.
3. Dyer O. Doctors suspended for removing wrong kidney. *British Medical Journal* 2004; **328**: 246.
4. Belyansky I, Martin TR, Prabhu AS, et al. Poor resident-attending intraoperative communication may compromise patient safety. *Journal of Surgical Research* 2011; **171**: 386–94.
5. Grint K, Holt C. Followership in the NHS 2011. London, UK: King's Fund. www.kingsfund.org.uk/sites/files/kf/followership-in-nhs-commississon-on-leadership-Management-keith-grint-claire-holt-kings-fund-may-2011.pdf (accessed 15/02/2016).
6. Gillespie BM, Gwinner K, Chaboyer W, Fairweather N. Team communications in surgery – creating a culture of safety. *Journal of Interprofessional Care* 2013; **27**: 387–93.
7. Flin RH, O'Connor P, Crichton M. *Safety at the sharp end: a guide to non-technical skills*. Hampshire: Ashgate Publishing Ltd, 2008.
8. Moneypenny MJ, Guha A, Mercer SJ, O'Sullivan H, McKimm J. Don't follow your leader: challenging erroneous decisions. *British Journal of Hospital Medicine* 2013; **74**: 687–90.
9. Bould MD, Sutherland S, Sydor DT, Naik V, Friedman Z. Residents' reluctance to challenge negative hierarchy in the operating room: a qualitative study. *Canadian Journal of Anesthesia* 2015; **62**: 576–86.
10. Friedman Z, Hayter MA, Everett TC, Matava CT, Noble LM, Bould MD. Power and conflict: the effect of a superior's interpersonal behaviour on trainees' ability to challenge authority during a simulated airway emergency. *Anaesthesia* 2015; **70**: 1119–29.
11. Bhangu A, Bhangu S, Stevenson J, Bowley DM. Lessons for surgeons in the final moments of Air France Flight 447. *World Journal of Surgery* 2013; **37**: 1185–92.
12. Okuyama A, Wagner C, Bijnen B. Speaking up for patient safety by hospital-based health care professionals: a literature review. *BMC Health Services Research* 2014; **14**: 61.
13. Kobayashi H, Pian-Smith M, Sato M, Sawa R, Takeshita T, Raemer D. A cross-cultural survey of residents' perceived barriers in questioning/challenging authority. *Quality and Safety in Health Care* 2006; **15**: 277–83.
14. Pian-Smith MC, Simon R, Minehart RD, et al. Teaching residents the two-challenge rule: a simulation-based approach to improve education and patient safety. *Simulation in Healthcare* 2008; **4**: 84–91.
15. Sydor DT, Bould MD, Naik VN, et al. Challenging authority during a life-threatening crisis: the effect of operating theatre hierarchy. *British Journal of Anaesthesia* 2013; **110**: 463–71.
16. Weiss M, Kolbe M, Grote G, et al. Agency and communion predict speaking up in acute care teams. *Small Group Research* 2014; **45**: 290–313.
17. Attride-Stirling J. Thematic networks: an analytic tool for qualitative research. *Qualitative Research* 2001; **1**: 385–405.
18. Fonteyn ME, Kuipers B, Grobe SJ. A Description of Think Aloud Method and Protocol Analysis. *Qualitative Health Research* 1993; **3**: 430–41.
19. Kennedy TJ, Regehr G, Baker GR, Lingard L. Preserving professional credibility: grounded theory study of medical trainees' requests for clinical support. *British Medical Journal* 2009; **338**: b128.
20. Lave J, Wenger E. *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press, 1991.
21. Calhoun AW, Boone MC, Miller KH, Pian-Smith MC. Case and commentary: using simulation to address hierarchy issues during medical crises. *Simulation in Healthcare* 2013; **8**: 13–19.
22. NHS England. Human Factors in Healthcare: A Concordat from the National Quality Board, 2013. www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf (accessed 27/01/16).
23. General Medical Council. Good Medical Practice. www.gmc-uk.org/static/documents/content/Good_medical_practice_-_English_1015.pdf (accessed 22/11/15).

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Thematic analysis of "Barriers to Challenging" from focus group transcripts (examples from FG transcripts).

2.2 Commenting on Beament T, Mercer SJ. Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia. *Anaesthesia* 2016; 71: 1332–1340

I am the senior author for this publication.

2.2.1 Why this paper was written?

It is well known that deficiencies in non-technical skills including not thinking ahead, not following procedures and not speaking up when concerns about risks are raised, can increase the chances of human error (66). Reid commented that speaking up is not exercised nearly enough in NHS facilities and that the likelihood of junior members of staff speaking up was entirely dependent on whether the voice and action of all staff were actively encouraged and valued by the organisation (67). Previous work undertaken on medical students that I was involved in and was published in *The British Journal of Hospital Medicine* concluded that erroneous decisions remain unchallenged not because of a failure to notice that the decision was wrong, but because of a reluctance to challenge the leader (68).

The following three critical events have elements of team members not challenging the leader and have all lead to individuals dying. I have summarised these events as they form the basis for initially conducting this research project.

2.2.1.1 Kegworth Air Disaster

On 8 January 1989, British Midland Flight 92, a Boeing 737-400 crashed on to the embankment of the M1 motorway near Kegworth whilst it was attempting to make an emergency landing at East Midlands Airport. A fan-blade had broken in the left engine which disrupted the air conditioning and filled the flight deck with smoke. The pilots believed that this indicated a fault in the ‘right engine’ as earlier models of the 737 ventilated the flight-deck from the right but this was not the case on the 737-400. The crew mistakenly shut down the functioning engine, and pumped more fuel into the malfunctioning one, which subsequently

burst into flames. Sadly, of the 126 people who were aboard, 47 died and 74 sustained serious injuries. Retrospective analysis showed that a number of human factors could critically affect the way a team undertook complex activities. At least one junior steward overheard the Captain say he was shutting down the 'right engine' when he had seen sparks and flames coming from the 'left' engine but felt unable to challenge this decision. Had this decision been challenged then perhaps this situational awareness mistake could have been avoided and lives not lost.

2.2.1.2 Elaine Bromley

The case of Elaine Bromley is very well known in the anaesthetic community and has been well publicised by Elaine's husband Martin Bromley OBE (69). On 29 March 2005, Elaine Bromley, a 37-year-old female presented for sinus surgery to a private hospital. She was deemed to be low risk for a general anaesthetic and was listed for a day case procedure. She was initially under the care of a Consultant Anaesthetist and following induction of anaesthesia, it proved impossible to firstly insert a flexible laryngeal mask and then to conventionally ventilate her lungs using a bag-valve-mask. Help was provided by another Consultant Anaesthetist and a Consultant ENT Surgeon. Despite there being a situation developing called *'can't intubate, can't oxygenate'* which anaesthetists practice drills on regularly, the national guidelines suggesting emergency front of neck access were not followed (29) and further failed attempts at intubation persisted. The clinicians involved appeared to be oblivious to the passing of time (for they had lost situational awareness) and Elaine underwent a prolonged period of hypoxia. The clinicians also were not challenged regarding their actions by any other members of the team present such as the Operating Department Practitioner or Scub Nurses who were aware that guidelines were not being followed. This case demonstrated a complete breakdown of non-technical skills in addition to failure to challenge the leader. Elaine did not regain consciousness again; and she died on 11 April 2005.

2.2.2.3 Gordon Reeves

Gordon Reeves, a 70-year-old male underwent what should have been a right nephrectomy at the Prince Philip Hospital in Llanelli, South Wales, in January 2000 (27). He was operated on by a Consultant Urologist and a Specialist Registrar. The left kidney was removed in error and this was felt to be compounded by the patient's x-ray being displayed the wrong way around and an incorrect entry had been made in the operation booking list. These errors occurred despite a medical student in the theatre knowing that the wrong site was being operated on. On discovering their mistake, the doctors carried out further surgery in an attempt to restore function to the chronically diseased right kidney which failed. Mr Reeves developed septicaemia and died five weeks after the first operation.

I was interested to investigate the barriers that existed to trainee anaesthetists not challenging consultant anaesthetists whilst working together in the operating theatre and I felt that this was important as trainees should act as responsible followers; and them not speaking out would put patients at risk of harm. This was the basis of the original research. In the article presented the challenging of seniors is defined as 'speaking up' and this centred on communicating other team members' doubts, differing opinions or potential problems about decision or course of action in medical care (70).

2.2.2 What was known at the time of writing?

An independent review into creating an open and honest reporting culture in the NHS conducted by Robert Francis in February 2015 noted that two particular barriers to challenging authority stood out and these were the fear of repercussions for an individual and their career, and the futility of voicing a concern as it was thought that nothing would be done about it (31). Additional, previously reported barriers to challenging reported in the medical literature are described in Table 2.1.

Table 2.1. Previously reported barriers to challenging

Poor intra-operative communication between senior and junior doctors (71)
The existence of a hierarchy in operating theatres (72).
Behaviour of seniors affecting challenging (73)
Motivation and clinical context in relation to the perception of risk to patients (74)
Individual factors including a lack of knowledge or confidence and poor communication skills (74)
The perceived safety of speaking up including the fear of reprisal, concerns of appearing incompetent, avoiding conflict and the perceived efficacy of speaking up including prediction that nothing will be done (75)
Fear of embarrassment of self or others (76)
Concern over being misjudged, fear of being wrong (76)
Fear of retribution (76)
Jeopardising an ongoing relationship (76)
Natural avoidance of conflict (76)
Concern for reputation (76)
No effect of operating room hierarchy on challenging behaviour (76)
Lack of training in effective challenging techniques (76)
Interindividual factors such as a lack of agency (assertiveness, persistence, independence) and the presence of communion (helpfulness, friendliness, sociability) (77)

2.2.3 What the paper added or contributed to the 'global' clinical community?

The analysis of both parts of the study determined the main barriers that anaesthetic trainees perceived to challenging consultants. One conclusion was that a new theme of the 'risk/cost benefit' existed in respect to anaesthetic trainees. This was exemplified by trainees effectively weighing up the potential consequences for patient harm of challenging or not challenging, versus the potential negative effects on themselves or their relationship with the senior in the context of the clinical situation/decision to be challenged. A key finding in the study was the effectiveness of non-verbal cues, predominantly used by more experienced trainees. Analysis of both parts of the study were used to formulate a thematic network model of 'barriers to

challenging seniors' (Figure 2.1) that combined previously known and newly described themes. The 'cost/risk-benefit' conceptual model (Figure 2.2) may prove useful in understanding the complicated decision-making process that exists underlying 'speaking up' behaviour.

2.2.4 Where are we now?

A recently published systematic review by Pattni (78) and colleagues entitled *'Challenging authority and speaking up in the operating room environment: a narrative synthesis'* reviewed 31 manuscripts around the subject of speaking up in the operating theatre and reviewed our original research. In addition to the conclusion that more senior trainees seemed to challenge more quickly, it also referred to another conclusion that we had made in terms of the cultural aspects to challenge. Friedman (73) and colleagues concluded that junior doctors struggled to challenge authority, but our study found the opposite and although our study was not statistically powered, it did suggest that trainees based in the UK challenged more effectively. It was hypothesized that this could well be due to the education and training provided in the Merseyside region around cases such as Elaine Bromley (79) and them being publicized in the anaesthetic literature (28).

The subsequent narrative synthesis performed by Pattni and colleagues concluded that hierarchy gradients, organisational culture, and education were the most frequently observed factors that affected an individual's ability to challenge authority (78). They also concluded that perceived barriers and enablers to speaking up were largely modifiable and that to promote speaking up within health teams would require organisations to cultivate a culture of open, safe communication in addition to an education programme regarding the importance of speaking up (78), which concurs with elements of our discussion.

2.2.5 Reflections on the methodology

Our original research project was split into two components and both elements are summarised and reflected on below

2.2.5.1 Part One. Focus Group Investigation of Senior Anaesthetic Trainees.

This consisted of a qualitative approach using verbatim transcriptions from a total of 12 anaesthetic trainees (ST3-7) from the Mersey Deanery from four facilitated focus group sessions each lasting about 30 minutes. Trainees were asked to discuss barriers that they perceived to exist to challenging consultants in their own and other specialties. The format of the focus group was to initiate questioning using a standardised set of predetermined open questions and then participants were encouraged to exchange anecdotes, clarify their views and remark on each other's experiences. A verbatim transcription was made of the interviews along with field notes and we analysed data using a thematic network analysis of known barriers and new, emerging barriers and this led to the formulation of 'barrier clusters'. In line with a thematic network, we noted keywords next to basic (first level) themes, and gradually grouped them into three common organising (second level) themes to explain the complexity by which these personal, organisational and situational factors interconnected and influenced the global theme of perceived barriers to challenging erroneous decisions by anaesthetic trainees. To increase the validity and reliability, we undertook a process of interrater conformability, whereby both authors independently coded the first transcript independently. We then engaged in a repeated coding process that led to agreement on most of the codes. Although an invitation was given to all Speciality Trainees (ST3-7) on the Mersey Rotation those who replied may have added a self-selected bias around challenging seniors. We may also have missed other aspects of challenging that have been experienced by those who did not participate.

2.2.5.2 Part Two. High Fidelity Simulation

We performed a quantitative analysis of a simulated high-fidelity airway crisis. A confederate (actor) consultant anaesthetist failed repeatedly to intubate a patient, and 13 junior anaesthetic trainees (first two years of training, CT1/CT2) were expected to challenge decisions that were clearly wrong in their individual scenario. This was combined with a qualitative analysis of barriers to challenging that were expressed and identified during the debrief session. Trainees were debriefed immediately following the simulations using video playback from their respective scenarios. The technique 'thinking aloud' (80) was used to explore displayed behaviours, barriers to speaking up and strategies used for challenging.

When CT1 (less than one-year experience) and CT2 trainees (less than 2 years' experience) were compared, the CT2s challenged quicker and ensured fewer intubation attempts, they established quicker adequate rescue oxygenation and ventilation and less simulated patient desaturation was observed. It has to be noted though that this was merely an observation and was not powered sufficiently to draw any meaningful statistical conclusions and in the planning stages of the study this was not an expected finding and so was not planned for. Limitations to this study were that the scenario was conducted in a simulation centre with a high-fidelity mannequin and that candidates may well have behaved very differently in real clinical practice. Some of the candidates had also worked with the consultant anaesthetist who was playing the role of the consultant anaesthetist in the scenario and this may have altered the way they would usually behave (or may not have), again this was not considered in the planning stages of the study and could have introduced a bias. This potential for bias could have been mitigated by the consultant who was intubating the mannequin (the confederate) being played by an actor or inviting another consultant who was unknown to the candidates.

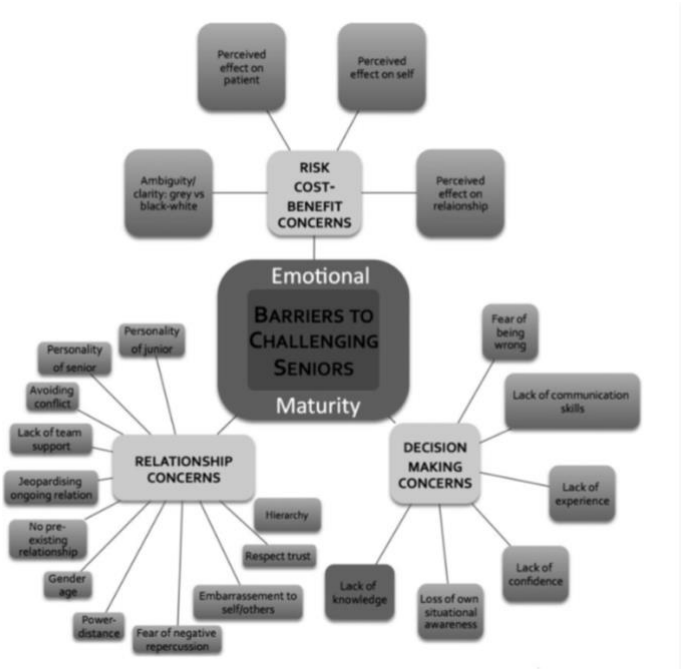


Figure 2.1. Thematic network diagram of barriers to challenging seniors

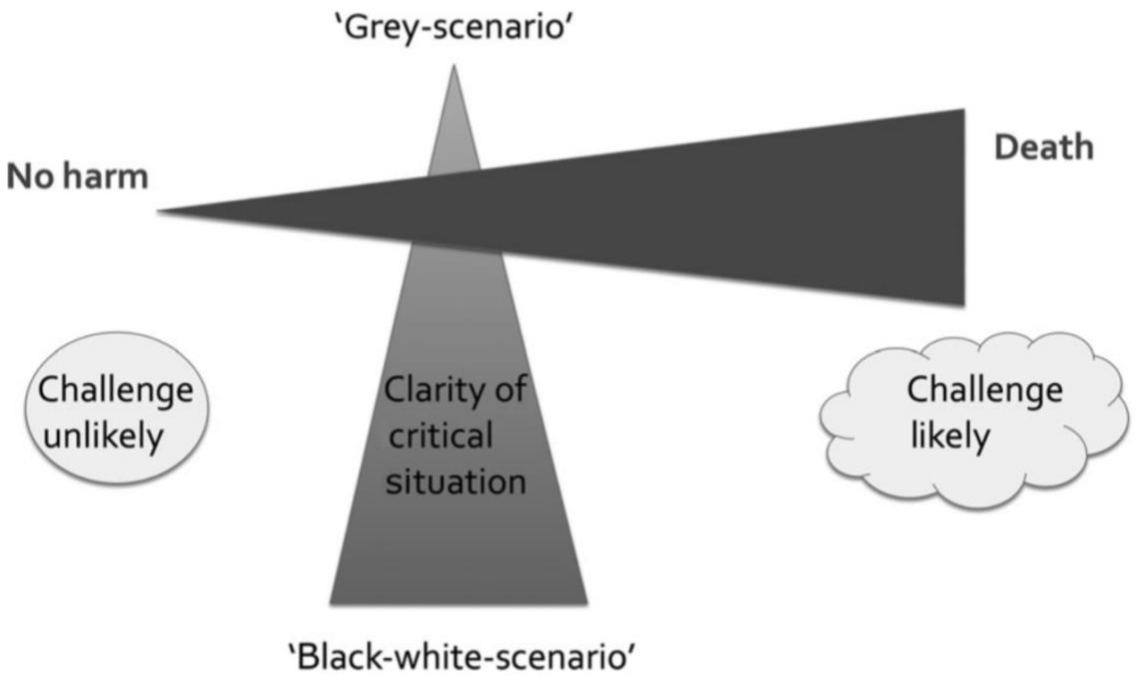


Figure 2.2. Model of Cost Benefit Analysis

2.2.6 Where are we now? Contribution of the Paper to Clinical Practice and What it says about me as a Researcher?

The impact that this article has made in the medical literature could be gauged by the fact that it has been cited 28 times. The Altmetric Attention score is 34 based on it being mentioned by 1 news outlet, in 1 blog and been mentioned on Twitter 27 times. There has also been engagement with this article 40 times on Mendeley. The impact factor of the Journal of *Anaesthesia* is 5.8 (2018-2019). This journal was chosen as it is read on a regular basis by consultant and trainee anaesthetists who are working in hospitals in the United Kingdom. The Journal is also circulated to members of the Association of Anaesthetists of Great Britain and Ireland. Two citations of this article were to develop my own work:

- Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. Human Factors in Preventing Complications in Anaesthesia. *Anaesthesia* 2018; 73(S1): 12-24
- Mercer SJ. Team-working, communication and use of communication aids and checklists (Book Chapter) *Section 2 - The impact of human factors in clinical practice in Decision-Making and Simulation in Obstetric Anaesthesia. Cambridge University Press.* 2019 Chapter 8 Pg 45-51.

The articles listed in Table 2.2 have also cited this publication (I have only listed articles published in English). Of note, it is a particularly pleasing to see that this paper is mentioned in a very recent editorial by Jennifer Weller(81) who I consider to be one of the world anaesthesia leads on patient safety and human factors. Several papers in Table 8 have cited our paper to define 'Speaking Up'.

Table 2.2. Publications citing Beament T, Mercer SJ. Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia. *Anaesthesia* 2016; **71**: 1332–1340

Paper	Summary
Tarrant C, Leslie M, Bion J, Dixon-Woods M. **A qualitative study of speaking out about patient safety concerns in intensive care units** ***Social Science & Medicine* 2017; 193: 8-15**	This study reports the outcomes of ethnographic observations and interviews of personnel working in intensive care units in England and focuses on concerns about patient safety and poor practice. The article concluded that formal reporting or communication training as the solution to giving voice to safety concerns was simplistic and that a more sophisticated understanding of social control was needed. Our work is cited here in the context that the challenging of seniors by trainees or junior members of the team was thought to be a particular issue of concern.
Almghairbi DS, Marufu TC, Moppett IK. Conflict resolution in anaesthesia: systematic review. *BMJ Simulation and Technology* 2019; 5: 1–7.	This is a systematic review that focuses on conflict resolution interventions and strategies and their impact on educational, behavioural and patient-level outcomes. The authors reviewed the concept of 'speaking up' and used the definition in our paper, *'speaking up with one's, and/or other team members doubts, differing opinions or potential problems about decision or course of action in medical care*' when conducting their literature search. The literature review revealed 3830 records initially and this was narrowed down to 11 eligible studies of which our paper was one of these. Our paper was then excluded at the full text screening stage. The article commented that an environment with and atmosphere of open and clear speaking up was essential and concluded that currently the evidence for training to improve conflict resolution in the clinical environment was sparse.
Martinez W, Lehmann LS, Thomas EJ. Speaking up about traditional and professionalism-related patient safety threats: a national survey of interns and residents. ***BMJ Quality and Safety* 2017; 26: 869–880.**	This paper reports the results of an anonymous survey of 1800 medical and surgical trainees on their attitudes about, barriers and facilitators for, and self-reported experience with speaking up. Our article is cited as one of a number of articles that describe the factors that influence trainees in speaking up about patient safety threats. The conclusions were that trainees commonly observed unprofessional behaviour yet were less likely to speak up about it compared with traditional safety threats even when they perceived high potential patient harm.

E Paradis, CR Whitehead. Beyond the lamppost: A proposal for a fourth wave of education for collaboration. *Academic Medicine* 2018; 93: 1457-1463	This article is a historical review of interprofessional learning described in 'four waves'. Our publication is cited with two other articles in the context that new health care professionals are not thought to be in a position to confront harmful and unsafe professional hierarchies. Another article that I have published was also cited in this publication (68)
Richard A, Pfeiffer Y, Schwappach DDL. Development and Psychometric Evaluation of the Speaking Up About Patient Safety Questionnaire. Journal of Patient Safety 2017 Aug 28.	This publication investigates speaking up in hospital organisations in Switzerland in the form of a questionnaire. Our article is cited just in the context that barriers to challenging have been investigated in the past.
Schwappach D, Sendlhofer G, Häsler L. Speaking up behaviors and safety climate in an Austrian University Hospital. International Journal for Quality in Health Care 2018; 30: 701–707	This publication sought to analyse speaking up behaviour and safety climate in an Austrian University Hospital via a questionnaire and concluded that only moderately frequent concerns were in conflict with frequent speaking up behaviours. Our article was cited whist defining speaking up.
Pattni N, Arzola C, Malavade A. Challenging authority and speaking up in the operating room environment: a narrative synthesis *British Journal of Anaesthesia* 2019; 122: 233-244.	This publication is a narrative synthesis which explores the literature on challenging authority in the operating room environment. Articles were identified as either discussion or review articles, observational or qualitative studies, or studies identifying the role of specific barriers or investigating the effect of educational interventions. It was noted that hierarchy, organisational culture and education were most frequent and that simulation studies were important (our study used simulation in part). Our article is a listed publication in the analysis and is cited as a source of qualitative research to offers insight into a trainees' perception of hierarchy in the operating room and the perceived barriers and enablers to speaking up.
Guris RJD, Duarte SS, Miller CR, et al. Training novice anaesthesiology trainees to speak up for patient safety. *British Journal of Anaesthesia* 2019 (In Press)	This publication had the primary aim of testing whether repeated simulation-based practice was of benefit to trainees in enabling them to speak up about patient management concerns. Our article was cited in respect to novice anaesthetists and also that different individuals are more predisposed to speaking out than others. The conclusion was that novice anaesthesia trainees benefited from simulation training to improve intrapersonal factors and communication.
Cooke G, Mitchell B. Silence is golden. *Medical Education* 2018; 52: 780–788	This editorial discusses pauses and hesitations in clinical practice in the context of the interactions between trainers and trainees. Our article is cited as hesitancy could be viewed as a feature of a learner about to learn. For learners, operating at the edge of their ability, but not too far beyond it, implies their actions are difficult, and therefore hesitation or uncertainty are features of a learner in the right space to progress. Here, interpreting uncertainty as incompetence, although perhaps correct at that moment, may also result in the missing of a golden opportunity for a teachable moment.
Price Y. Barriers to challenging senior anaesthetists' decisions. *Anaesthesia* 2017; 72: 272.	This is a correspondence to the editor in response to our article. The author commented that it was disappointing that patients were potentially at risk

	due to trainee's reluctance to speak up and challenge senior colleagues. The author suggested that a reluctance to challenge may have been due to a lack confidence in knowledge. They also commented that the cost-risk conceptual model was interesting and should be used in other clinical decisions involving significant patient risk and uncertain management.
Ng GWY, Pun JKH, So EHK, et al. Speak-up culture in an intensive care unit in Hong Kong: a cross-sectional survey exploring the communication openness perceptions of Chinese doctors and nurses. *BMJ Open* 2017; 7: e015721	This study uses a questionnaire to explore the perception of issues in ICU communication in Chinese Doctors and Nurses, their reasons for speaking up and the possible factors and strategies to promote speaking up. Our article is cited in the context that indirect speaking strategies by the Chinese to maintain harmony may also be related to the training that they receive on human factors involved in speaking up. It is stated that an inability to challenge authority is often attributed to a lack of training in conflict management. Another abstract that I have published was also cited in this article (82).
Smith AF, Plunkett E. People, systems and safety: resilience and excellence in healthcare practice. *Anaesthesia* 2019, 74, 508–517	This editorial describes safety science in terms of three 'ages', defined as the 'age of technology', the 'age of human factors' and the 'age of safety management'. The authors argue that clinical and organisational work can be made safer by fostering excellence and promoting resilience in addition to talking negative comments. Our article is cited in the context that trainees should be able to raise concerns.
Bringans C. Medicine Needs Medical Student-Scientists: Update on an Old Theory. *The New Zealand Medical Student Journal* 2017; 25	This article is a discussion on medical students 'speaking out'
Schwappach D, Sendlhofer G, Kamolz L-P, Ko¨le W, Brunner G. Speaking up culture of medical students within an academic teaching hospital: Need of faculty working in patient safety. *PLoS ONE* 2019; 14(9): e0222461.	This paper reports a survey amongst medical students using a validated questionnaire. Our paper is quoted to define 'speaking up'. The study concluded that the more experienced the student the more frequently they reported perceived patient safety concerns or rule violations.
Etherington N, Wu M, Cheng-Boivin O, Larrigan S, Boet S. Interprofessional communication in the operating room: a narrative review to advance research and practice *Canadian Journal of Anesthesia* 2019; 66: 1251–1260	This paper is a narrative review that outlines the importance of interprofessional communication for surgical patient safety. It also maps the barriers and facilitators to communication and highlights key strategies for enhancing its quality in the operating room. Our paper is cited to emphasise that there are many barriers to speaking up in the operating room (e.g., hierarchy, lack of training, relationships, personality). A research agenda to inform best practices in interprofessional operating room communication has been suggested based on this work.
Weller JM, Long JA. Creating a climate for speaking up. British Journal of *Anaesthesia* 2019; 122: 710-713	This is an Editorial in the *British Journal of Anaesthesia* and provides an overview of the literature on speaking up. The authors reveal an imbalance in efforts to promote speaking up and note that the predominance of studies are actually directed at junior staff. Our paper is cited and commented that we undertook a useful synthesis of studies exploring barriers to speaking up. The

	editorial comments that barriers are due to poor communication between senior and junior medical staff, the behaviour of senior staff, the perceived hierarchy in operating theatre teams, and the low status of an individual.
Newsam R. Operating department practitioners and midwives: The undervalued obstetric care collaboration. *British Journal of Midwifery* 2018; 26. https://doi.org/10.12968/bjom.2018.26.11.714	This is a case study of communication on the labour ward and gives an example of when communication broke down between a junior and senior practitioner.
Novak A. Improving safety through speaking up: An ethical and financial imperative. *Journal of Healthcare Risk Management* 2019; 39: 19-27	This article describes an initiative at one institution to encourage staff to 'Speak Up!'
Best JA, Kim S. The FIRST Curriculum: Cultivating Speaking Up Behaviors in the Clinical Learning Environment. *The Journal of Continuing Education in Nursing* 2019; 50: 355-361	This paper describes an educational program to encourage speaking up. The conclusion is that training improved participants motivations to speak up concerns.
Toy S, Guris RJ, Duarte SS, Dwivedi P. Development of a scale to measure intrapersonal factors influencing speaking up in the operating room. *Perspectives on Medical Education* 2019; 8: 253–260	This paper reported on the development of a scale to measure intrapersonal factors that may influence speaking up behaviour in the operating room. Our research was cited as one article that identified individual factors as the main barriers to speaking up.

The following individual thesis have also cited this article which demonstrates that my work is now starting to be acknowledged in current research and being further developed.

Ann-Sofie Sundqvist (PhD Thesis)

- **Title:** Perioperative patient advocacy - having the patient's best interests at heart
- **Institution:** Örebro University

Şenay Sarmasoğlu (Program of Medical Education Master of Science Thesis)

- **Title:** Intern doctors' likelihood of speaking up for patient safety
- **Institution:** Republic of Turkey Hacettepe University Graduate School of Health Sciences

Jamie White (PhD Thesis)

- **Title:** Empowering medical personnel to challenge through simulation-based training
- **Institution:** University of Birmingham

2.2.7 Where this paper places me with reference to being at the forefront of my area of professional practice.

I have used the knowledge we discovered from this research paper to present at the following invited national meetings with multidisciplinary audiences.

Title: **Simulation for Trauma Training**
Meeting: Trauma Care Conference
Location: Yarnfield Conference Centre, Stafford
Date: 6 March 2019

Title: **Wrong Site Block**
Meeting: Royal College of Anaesthetists Updates Meeting
Location: Hilton Hotel, Liverpool
Date: 26 November 2018

Title: **Improving Trauma Teams. Understanding Why Teams Don't Work**
Meeting: Cambridge Trauma Conference
Location: Churchill College Cambridge
Date: 28 April 2018

Title: **Human Factors in Complex Trauma**
Meeting: Association of Anaesthetists of Great Britain and Ireland Annual Congress
Location: BT Convention Centre, Liverpool
Date: 28 September 2017

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan. Arul S, Pugh H, Mercer SJ, Midwinter M *Annals of The Royal College of Surgeons of England* 2015; **97**: 262-268

3. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Arul (50%) Original idea for manuscript, developed Trauma WHO, collected data in Camp Bastion, wrote 1st draft. S Mercer (20%) developed Trauma WHO, subsequent revisions. H Pugh (20%) developed Trauma WHO, subsequent revisions. M Midwinter (10%) Manuscript revisions.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
S Arul	Signed electronically Suren Arul	suren.arul@nhs.net
H Pugh	Signed electronically Harry Pugh	hpugh1@nhs.net
M Midwinter	M Midwinter	m_midwinter@hotmail.com

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	
	(Director of Studies/Advisor)		

6. Signature of Faculty Research Degrees Administrator

Signature:		Date:	
	(Faculty Research Degrees Administrator)		

RCS ADVANCING SURGICAL STANDARDS

TRAUMA SURGERY

Ann R Coll Surg Engl 2015; **97:** 262–268
doi 10.1308/003588414X14055925060875

Human factors in decision making in major trauma in Camp Bastion, Afghanistan

GS Arul[1], HEJ Pugh[2], SJ Mercer[3], MJ Midwinter[4]

[1]212 Field Hospital, Sheffield, UK
[2]16 Medical Regiment, Colchester, UK
[3]Aintree University Hospital NHS Foundation Trust, UK
[4]Royal Centre for Defence Medicine, Birmingham, UK

ABSTRACT

INTRODUCTION The concentration of major trauma experience at Camp Bastion has allowed continuous improvements to occur in the patient pathway from the point of wounding to surgical treatment. These changes have involved clinical management as well as alterations to the physical layout of the hospital, training and decision making. Consideration of the human factors has been a major part of these improvements.

METHODS We describe the Camp Bastion patient pathway with the communication template that focused decision making at various key moments during damage control resuscitation and damage control surgery (DCR–DCS). This system identifies four key stages: 'command huddle', 'snap brief', 'sit-reps' (situation reports) and 'sign-out/debrief'. The attitude of staff to communication and decision making is also evaluated.

RESULTS Twenty cases admitted to Camp Bastion with battlefield injuries were studied from 6 September to 6 October 2012. Qualitative responses from 115 members of staff were collected. All patients were haemodynamically shocked with a median pH of 7.25 (range: 6.83–7.40) and a median of 18 units of mixed red cells and plasma were transfused. In 89% of instances, theatre staff were aware of what was required of them at the beginning of the case, 86% felt there were regular updates and 93% understood what was required of them as the case progressed.

CONCLUSIONS The evolution of the hospital at Camp Bastion has been a unique learning experience in the field of major trauma. The Defence Medical Services have responded with continuous innovation to optimise DCR–DCS for seriously injured patients. Together with the improvements in clinical care, a communication and decision making matrix was developed. Staff evaluation showed a high degree of satisfaction with the quality of communication.

KEYWORDS

Trauma – Military – War – Afghanistan – Battlefield injuries – Gunshot wounds – Blast injuries – Landmines

Accepted 29 July 2014

CORRESPONDENCE TO

Suren Arul, E: suren.arul@bch.nhs.uk

Damage control resuscitation (DCR) and damage control surgery (DCS) are established UK military doctrine for the initial management of severely injured patients.[1] However, taking the theory and converting it into a practical, workable solution has required a continuous process of meticulous data collection, research, audit and service improvement.[2] The actual patient pathway has therefore evolved significantly from the early days of the tented hospital to the present layout in the purpose built hospital.[3] Each step in the patient transfer on arrival to Camp Bastion has been considered carefully, from the use of tourniquets[4] at the point of injury in order to control catastrophic haemorrhage to the medical emergency response team.[5] These medical teams arrive by Chinook helicopter to collect patients for transfer to Camp Bastion; the purpose is to bring care as far forwards as possible and minimise the time to reach medical treatment.

Not only has clinical practice evolved but the physical floor plan has changed in Camp Bastion to improve the ergonomics of transfer. Furthermore, there has been a concentration on human factors to optimise leadership, teamwork and the multidisciplinary approach.[6]

The need for urgent treatment in the most severely injured patients, especially in a busy trauma hospital such as at Camp Bastion where multiply injured casualties are often evacuated from the battlefield to the emergency department (ED) in a short time, meant that established communication techniques sometimes failed to keep the team adequately informed and updated while dealing with the casualty.[7] The authors of the '10 seconds for 10 minutes' principle identified

in a simulation laboratory that even in emergencies, taking time to assess the situation, which aims to teach followership and leadership among other skills, improved decision making and made the team work effectively.[8] The newly established *European Trauma Course* teaches teamworking and leadership, uses a five-second check done by the team leader on the arrival of the casualty, prior to the team starting work.[9,10] This allows the team leader and team members an overview of the patient, which is vital to maintaining situational awareness and forming a mental model.

Both approaches place human factors and communications at the very centre of the management of sick patients. Similar evidence is published on the need for concentrating on human factors in the operating theatre.[11–14] Best practice assumes good communication to sequence and coordinate the processes. This is taught in detail by the Defence Medical Services with intensive training for revision just before deployment.[15–17] The World Health Organization (WHO) surgical safety checklist, introduced in 2009,[18–20] helps to reduce 'never events' and improves briefing of the team.[21] It has also been reported to reduce hospital mortality.[21] It was not, however, designed to optimise communication in the rapidly changing situation faced by the ED and operating room (OR) teams dealing with a severely injured patient. A discussion paper published in 2012 therefore sought to improve and streamline communication specifically during the DCR–DCS sequence.[22]

The patient pathway

Figure 1 shows a diagrammatic representation of the front end of the Camp Bastion hospital footprint while Figure 2 shows the communications system, known as the 'Trauma WHO Checklist'. Virtually all injured patients arrived by helicopter, transferred either by the British or American teams landing at the helicopter landing site approximately 200 metres from the hospital. Transfer was by ambulance to the front of the ED with triage occurring at several stages in the process. The numbers below relate to the points on Figure 1:

1. Detailed information was sent directly from the Patient Evacuation Coordination Cell to the hospital, informing them of the type of incident as well as the number and severity of casualties due to arrive. This allowed the consultant of the ED to call out the trauma teams, and to allocate relevant resources and staff to the correct number of beds in the ED and theatres.
2. The ED consultant met the ambulances on arrival and allocated them to a resuscitation bay. Although this was usually decided in advance based on the radioed information, it occasionally changed again.

    2.1. While the patient was being unloaded by the reception teams, the senior transferring clinician (doctor or paramedic) gave the accepting team a briefing based on the 'ATMIST' handover system (Table 1). It was vital that the trauma team were disciplined and remained focused and silent during the handover. Often the prehospital doctor entered the ED prior to the patient, allowing for less distraction. However, if the patient arrived at the same time, he or she would only have been looked at to confirm there

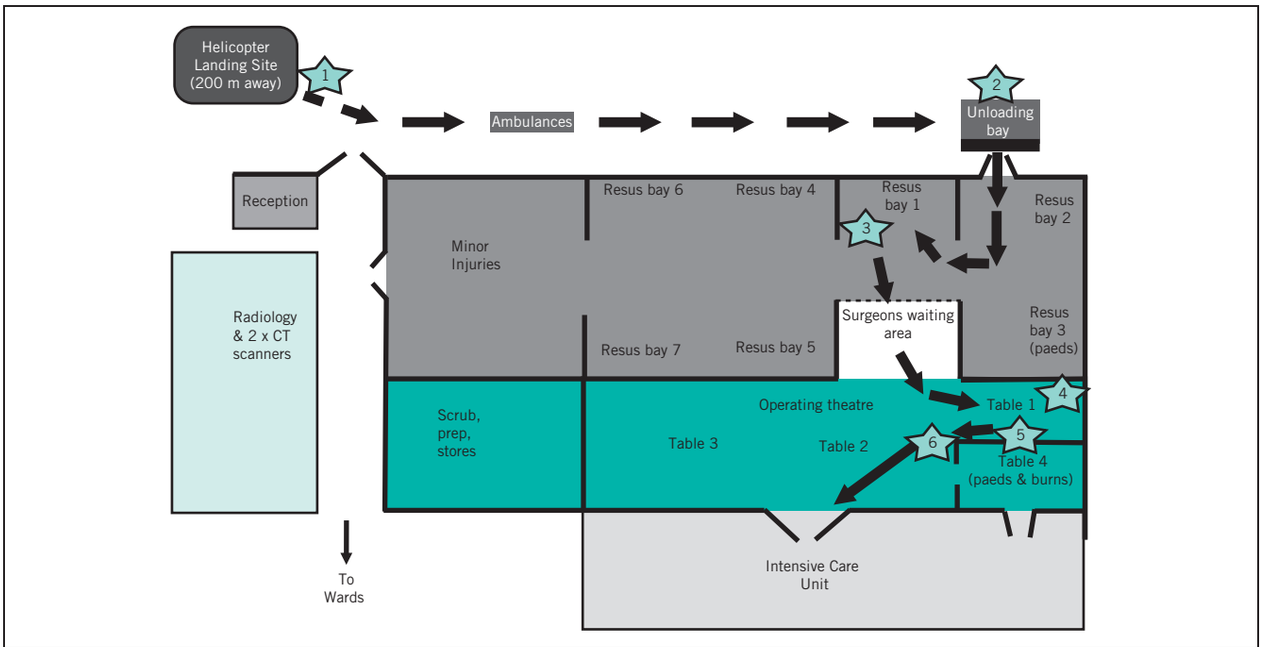


Figure 1 Diagrammatic representation of the British military hospital at Camp Bastion and the patient pathway during damage control surgery (not to scale)

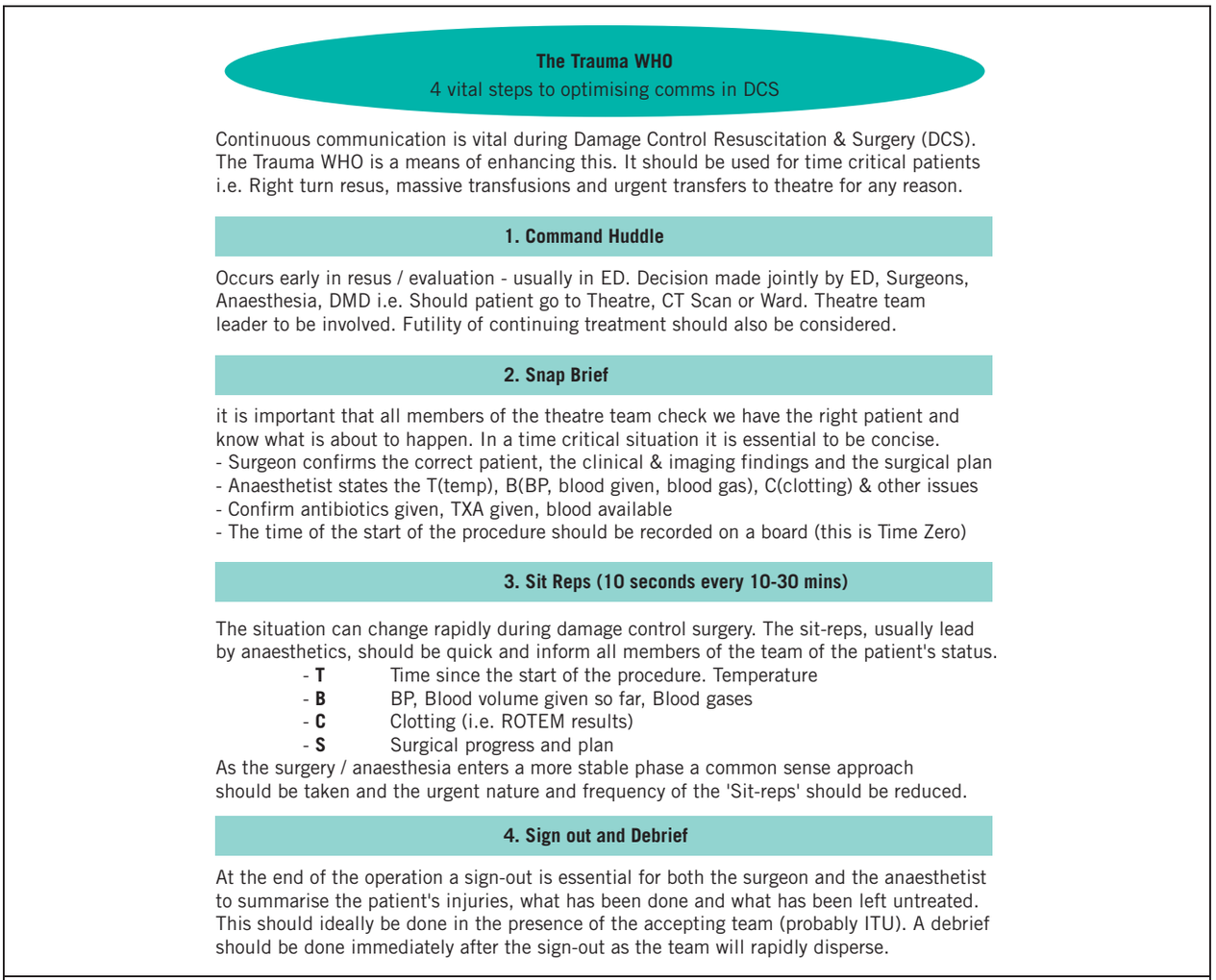


Figure 2 Aide-mémoire for time critical surgery, especially damage control resuscitation and surgery

Table 1 'ATMIST' handover

A	**A**ge of patient
T	**T**ime of incident
M	**M**echanism of injury
I	**I**njuries (from top to toe)
S	vital **S**igns
T	**T**reatments given so far

was no ongoing catastrophic haemorrhage or airway obstruction. All other treatment commenced after the handover had finished.

3. The patient arrived in the resuscitation bay on a stretcher and was transferred to the hospital trolley. A <C>ABC approach[4] to injury identification and management was followed under the leadership of the ED team leader using a horizontal resuscitation approach.[23]

3.1. Occasionally, a severely injured patient with ongoing haemorrhage may have gone straight to the operating theatre without stopping in an ED bay, known as 'right turn resuscitation'.[24] (The direction of patient flow has evolved over recent years so readers will note from the floorplan that at the time of writing it was actually a left turn to the theatres.) In this case, the entire ED trauma team stayed with the patient to do the primary survey and identify injuries while the surgeon/anaesthetist managed the catastrophic haemorrhage.

3.2. Once the initial assessment was complete, the ED team leader called a 'command huddle' in conjunction with the anaesthetist and the senior surgeon, to establish appropriate treatment (or possible futility), which was usually going either to theatre, to computed tomography or straight to the ward.[22]

4. The majority of patients with penetrating battlefield injuries went to the OR. On arrival, the anaesthetist called time out for a 'snap brief', modelled on the WHO checklist but streamlined specifically for the most urgent time critical patients. It must be remembered that unlike an elective operating list, these patients may arrive in theatre within minutes of arriving in the department so the theatre team could have very little warning of the patient or what to expect. As a result, it is essential that the key information is communicated to the entire team in a set format to make sure that nothing is missed.
5. The time of the start of surgery was noted on a board in theatre and documented during the snap brief so that the importance of time was not lost.

5.1. The situation changes rapidly during DCS as new injuries are discovered and the patient's physiology fluctuates in regard to his or her injuries and treatment. Furthermore, multiple surgical teams could be working on the same patient. 'Sit-reps' (situation reports) were used every 10–30 minutes to keep the team updated of progress. The mnemonic 'TBCS' helped the team leader to remember the critical information to be covered (explained in more detail in Appendix 1 – available online.) Bringing the vital physiological parameters and the surgical progress together like this regularly helps reduce the risks of tunnel vision or loss of situational awareness. It also focuses the team to review their surgical plan and change it if necessary.

6. At the end of surgery a 'sign-out' should be done. At Camp Bastion, the intensive care unit (ICU) team came to collect the patient. The sign-out is essential for both the surgeons and the anaesthetist to inform the receiving ICU team as well as all the other members of the theatre team about the patient's injuries, what has been done and what is left to do. By definition, DCS will focus on the critical injuries causing haemorrhage or contamination so many things will have been left to be dealt with at second-look surgery when the patient's physiology has improved.

6.1. A debrief was done at the end before the team dispersed to other activities. This is important for clinical feedback and also to allow staff to express their feelings about the sometimes complex emotional, moral and ethical dilemmas with which they have dealt.

6.2. Further analysis of the case continued over the following days, including a weekly telephone conference morbidity and mortality meeting that involved both the Queen Elizabeth Hospital in Birmingham and the US medical facility in Landstuhl, Germany, until all learning points had been extracted and dealt with.

Methods

Approval was obtained from the director of the Joint Medical Command prior to the start of the project (RCDM/Res/Audit/1036/12/0230) as well as from the deployed medical director of the hospital. Theatre staff attitudes to communication during the management of major trauma were investigated by means of a standardised questionnaire. This was prepared with advice from experts in psychology and communication, and included 12 questions as well as a visual analogue scoring system. This was used to get information on the case and record the reactions of all members of the team associated with the case. Free text was also used to allow staff to express their personal opinions. The questionnaire was confidential. The case inclusion criteria were that the patient was severely injured and required DCS.

Although the Trauma WHO Checklist paper had already been published[22] and widely distributed in predeployment training, the surgeons, anaesthetists and theatre staff were briefed again in Afghanistan prior to the start of the project on the format for communication during cases in which it was likely that DCR–DCS would be required. Posters were placed around the theatre as an aide-mémoire for the communication system proposed. Data were anonymised for both the patient and the staff, and recorded on a standard Excel® spreadsheet (Microsoft, Redmond, WA, US).

Results

Twenty cases were studied in a thirty-day period during September 2012. Responses from 115 members of staff were collected. Patients were all admitted to the hospital at Camp Bastion with either gunshot or blast injuries. They were haemodynamically shocked with a median pH of 7.25 (range: 6.83–7.40), a median base excess of -7mEq/l (range: 0–-24mEq/l) and a median lactate of 4.99mmol/l (range: 1.9–14.6mmol/l]. A median of 18 units of mixed packed red cells and fresh frozen plasma were transfused (9 units of each in a 1:1 ratio). The median time from arrival to the first incision in theatre was 56 minutes (range: 3–110 minutes). There was one death in this group.

The 115 responses from staff are shown in Table 2 (30 from surgeons, 23 from anaesthetists, 18 from operating department practitioners, 18 from scrub nurses, and 26 from others such as runners and transfusion staff). Overall, 88% of the theatre staff either agreed or strongly agreed that they were aware of the injuries at the beginning of the case, 91% said there were regular updates during the case and 99% understood what was required of them as the case progressed. Teamwork was found to be effective by 93% of staff members and the same proportion believed there was good communication throughout the case. Over two-thirds (69%) felt that regular sit-reps contributed to

Table 2 Results of questionnaire for optimising communications

Please answer the following questions by circling one response only, using the scale below.

	0	1	2	3	4
	Disagree strongly	Disagree	Neutral	Agree	Agree strongly

		0	1	2	3	4
At the start (ie after the snap brief)						
Q1	At the start, were you aware of the patient's injuries?	3%	6%	4%	20%	68%
Q2	At the start of the operation, did you understand the surgical plan?	1%	2%	9%	19%	69%
Q3	Did you know what was required of you at the beginning of the case?	1%	1%	2%	11%	85%
During the case						
Q4	Were there regular updates during the case?	1%	4%	4%	20%	71%
Q5	Were changes or problems during the case communicated effectively to the entire team?	0%	1%	11%	20%	68%
Q6	Did you feel that you knew what was happening during the case?	0%	2%	4%	21%	73%
Q7	Did you know what was required of you as the case progressed?	0%	0%	1%	7%	92%
Communication						
Q8	Did the team work effectively throughout the case?	0%	2%	6%	15%	78%
Q9	Was there good communication during the operation?	1%	4%	2%	20%	73%
Q10	Did you feel regular sit-reps helped to improve communication?	0%	6%	15%	20%	58%
Q11	Did you feel that you could communicate freely during the case?	0%	4%	3%	10%	83%
Q12	Were regular sit-reps helpful?	3%	7%	21%	34%	35%

improved communication with only 10% feeling that they could become annoying or unhelpful. Free text was allowed to feed back specific comments (Table 3).

Discussion

The medical treatment facility at Camp Bastion has been a unique environment for the treatment of the severely injured since it opened in 2006. A process of data collection, audit and service improvement has led to continual innovation and improvement.[25] DCR–DCS is now the standard of care for the severely injured patient,[1,26] and every step in the pathway from point of wounding to the evacuation back to the UK has been considered in detail to minimise the delays and optimise treatment. With the closure of the hospital, we feel it is important to capture the logistical and clinical changes that occurred during its lifetime.

In the complex environment of managing major trauma, teamwork and non-technical skills are essential for peak performance.[12,14,16,17,27] Training started for the entire theatre team before arrival in Camp Bastion in the form of a 72-hour whole-hospital simulation.[28] Care was consultant-delivered throughout the patient journey, unlike in the National Health Service where it is often only consultant-led.[29] It is this relatively recent acceptance of the complexity of both medicine in general and the operating theatre environment in particular[30] that led to the development of the checklist. Gawande found that this produced a 36% reduction in complications and a 47% reduction in deaths.[31] The result was the worldwide acceptance of the WHO checklist[18,19] and the British Defence Medical Services formally introduced it to the hospital at Camp Bastion in 2010.

The original WHO checklist includes 19 questions and takes approximately 2–5 minutes to complete. Unlike most surgery, where the operation is seen as a distinct entity from the preoperative or ward phase and the operative plan is clear at the preoperative stage, severely injured patients require treatment along the DCR–DCS sequence in which resuscitation, identification of injuries, rapid surgical control of bleeding and management of life threatening injuries are integrated seamlessly and occur concurrently.[1] Human factors are essential in maintaining good teamwork.[16,17] However, a single point checklist such as the WHO checklist is not sufficient to promote optimal intraoperative team communication because the knowledge of the injuries sustained and the dynamically changing physiological derangement requires the surgical management plan to evolve in light of this change.

Table 3 Free text comments from theatre staff

Comments
Anaesthetist: Unstable patient. Comms very helpful to understand what was going on and how to proceed.
Anaesthetist: Feel the sit-reps formalises what is already done. Will probably become more user friendly with repetition.
Operating department practitioner: Patient's injuries were not obvious and as patient hadn't had a CT I knew what was required of me but at times I felt overwhelmed with tasks. Sit-reps worked well to tie everything together.
Surgeon: The patient had dropped systolic blood pressure down to 60 without the surgical team being informed. Poor communication but problem highlighted by the sit-reps.
Scrub nurse: The sit-reps were done at a time dictated by the anaesthetist. This made the operation and communication more smooth.
Transfusion team: This was the best case I've worked on yet. The anaesthetist was extremely professional. He discussed the plan at logical intervals, he explained his clinical decisions, plans for products and follow-up tests were talked about with enough time to react. I appreciated his teaching with me as well. I was also glad when the surgeons discussed their plans at the beginning and could gauge some of the ups and downs ahead to communicate product needs to emergency department staff. Back in the emergency department also at the beginning, the anaesthetist told us the target BP so at any given time, it was open communication to discuss a bolus. Great case. Thank you.

The fact that the hospital at Camp Bastion was probably one of the busiest major trauma units in the world provided the background against which we could trial a specific protocol of communication for trauma. Following discussions within the Defence Medical Services, it was felt that to promote good communications for severely injured patients, these would need to start in the resuscitation room, continue throughout the operation and finish with a formal sign-out; debrief should be done at this point as the trauma team will usually disperse rapidly.

All military doctors, nurses and theatre personnel involved were trained jointly in both trauma management and teamwork. This occurred using cadavers for DCS and high fidelity simulation for teamwork on the *Military Operational Surgical Training* course.[15] Furthermore, to learn to how to manage casualty flow, a whole-hospital simulation in a hanger was used. Considered vital in all aspects of military activity, clear communication is confirmed by the fact that 96% of respondents had a clear understanding of their role at the beginning of the case and that 99% understood what was required of them as the case progressed reflects the fact that teamwork is already well honed in this small group of clinicians. The biggest single innovation for this project was the addition of the sit-reps, which formalised the communication during the progress of the case.

Having some flexibility in the timing of sit-reps was found to be beneficial (eg waiting for the results of the blood gases or thromboelastometry). Recognition that a key part of managing the trauma patient is at the time of transition from the OR to ICU led to the addition of the sign-out so that it could be made clear to all staff and the team accepting the patient exactly what had been performed as well as the goals for management for the next few hours and days.

By identifying just a few key moments in the management of complex trauma, we can focus minds on the importance of good communication even when the team is engrossed in performing DCS. This concept was well illustrated by the '10 seconds for 10 minutes' principle.[8] The major advance on the WHO checklist described in our guideline is the use of the sit-reps, which seek to continue good communication practice in the intraoperative phase and to remind the team of maintaining a dialogue.

Although this concept was already well known, it is frequently characterised by open questions such as 'how are things going?' while responses such as 'we are keeping up' are too vague to allow for meaningful dialogue and decision making. A simple protocol based on the mnemonic 'TBCS' reminds us of the importance of giving a minimum dataset of information to get a fuller picture of the patients' problems, their current physiological status and the evolving surgical plan. It does not intend, however, to reduce other forms of communication that may be considered relevant. Gawande found one unexpected result of the original WHO checklist: it seemed to improve management in areas not covered by the checklist presumably by facilitating better communication.[30] We had similar findings, reflected in the comments of the trauma team (Table 3).

Conclusions

This article has described the Camp Bastion system of major trauma management, in which every moment of the patient journey has been considered. Numerous improvements in clinical management have been described including DCS,[1] use of thromboelastometry[32] and massive transfusion protocols.[33] In addition, human factors and good communication have been placed at the very centre of our management approach. Identifying key moments for vital communication in the DCR–DCS process and, in particular, the introduction of sit-reps has further enhanced the communication in an already good team. As with all guidelines, repeated use will encourage all the team members to become comfortable with the terms and the process. We would therefore recommend that this guideline be introduced for communication in DCR–DCS and be taught as part of the team preparations.

Acknowledgements

The authors would like to thank the staff of Herrick 16B and Colonel James Ralph (Deployed Medical Director) for their participation in this study. We are also grateful to Professor R Flin and Mr M de Rond for their advice in preparing the visual analogue questionnaire.

The views expressed in this paper are those of the authors and not of the Ministry of Defence.

References

1. Midwinter MJ. Damage control surgery in the era of damage control resuscitation. *J R Army Med Corps* 2009; **155**: 323–326.
2. Smith J, Hodgetts T, Mahoney P *et al*. Trauma governance in the UK defence medical services. *J R Army Med Corps* 2009; **153**: 239–242.
3. Horne S, Smith JE. Preparation of the resuscitation room and patient reception. *J R Army Med Corps* 2011; **157(3 Suppl 1)**: S267–S272.
4. Hodgetts TJ, Mahoney PF, Russell MQ, Byers M. ABC to <C>ABC: redefining the military trauma paradigm. *Emerg Med J* 2006; **23**: 745–746.
5. Haldane AG. Advanced airway management – a medical emergency response team perspective. *J R Army Med Corps* 2010; **156**: 159–161.
6. Mercer S, Arul GS, Pugh HE. Performance improvement through best practice team management: human factors in complex trauma. *J R Army Med Corps* 2014; **160**: 105–108.
7. Arul GS, Bowley DM, DiRusso S. The use of Celox gauze as an adjunct to pelvic packing in otherwise uncontrollable pelvic haemorrhage secondary to penetrating trauma. *J R Army Med Corps* 2012; **158**: 331–333.
8. Rall M, Glavin RJ, Flin R. The '10-seconds-for-10-minutes principle'. *Bull R Coll Anaesth* 2008; **51**: 2,614–2,616.
9. Thies K, Gwinnutt C, Driscoll P *et al*. The European Trauma Course – from concept to course. *Resuscitation* 2007; **74**: 135–141.
10. Lott C, Araujo R, Cassar MR *et al*. The European Trauma Course (ETC) and the team approach: past, present and future. *Resuscitation* 2009; **80**: 1,192–1,196.
11. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. *Br J Anaesth* 2010; **105**: 38–44.
12. Flin R, Yule S, Paterson-Brown S *et al*. Teaching surgeons about non-technical skills. *Surgeon* 2007; **5**: 86–89.
13. Manser T, Foster S, Flin R, Patey R. Team communication during patient handover from the operating room: more than facts and figures. *Hum Factors* 2013; **55**: 138–156.
14. Mitchell L, Flin R, Yule S *et al*. Thinking ahead of the surgeon. An interview study to identify scrub nurses' non-technical skills. *Int J Nurs Stud* 2011; **48**: 818–828.
15. Mercer SJ, Whittle C, Siggers B, Frazer RS. Simulation, human factors and defence anaesthesia. *J R Army Med Corps* 2010; **156(4 Suppl 1)**: 365–369.
16. Mercer SJ, Whittle CL, Mahoney PF. Lessons from the battlefield: human factors in defence anaesthesia. *Br J Anaesth* 2010; **105**: 9–20.
17. Midwinter MJ, Mercer SJ, Lambert AW, de Rond M. Making difficult decisions in major military trauma: a crew resource management perspective. *J R Army Med Corps* 2011; **157(3 Suppl 1)**: S299–S304.
18. World Alliance for Patient Safety. *WHO Guidelines for Safe Surgery*. 1st edn. Geneva: WHO; 2008.
19. World Health Organization. *Surgical Safety Checklist*. Geneva: WHO; 2009.
20. Haynes AB, Weiser TG, Berry WR *et al*. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 2009; **360**: 491–499.
21. van Klei WA, Hoff RG, van Aarnhem EE *et al*. Effects of the introduction of the WHO 'Surgical Safety Checklist' on in-hospital mortality: a cohort study. *Ann Surg* 2012; **255**: 44–49.
22. Arul GS, Pugh HE, Mercer SJ, Midwinter SJ. Optimising communication in the damage control resuscitation – damage control surgery sequence in major trauma management. *J R Army Med Corps* 2012; **158**: 82–84.
23. Smith JE, Russell RJ, Horne S. Critical decision-making and timelines in the emergency department. *J R Army Med Corps* 2011; **157(3 Suppl 1)**: S273–S276.
24. Tai NR, Russell R. Right turn resuscitation: frequently asked questions. *J R Army Med Corps* 2011; **157(3 Suppl 1)**: S310–S314.
25. Hodgetts TJ. A roadmap for innovation. *J R Army Med Corps* 2014; **160**: 86–91.
26. Jansen JO, Thomas R, Loudon MA, Brooks MA. Damage control resuscitation for patients with major trauma. *BMJ* 2009; **338**: b1778.
27. Flin R, Youngson G, Yule S. How do surgeons make intraoperative decisions? *Qual Saf Health Care* 2007; **16**: 235–239.
28. Arora S, Sevdalis N. HOSPEX and concepts of simulation. *J R Army Med Corps* 2008; **154**: 202–205.
29. Fries CA, Rickard RF. Surgical training in Camp Bastion, Afghanistan. *J R Nav Med Serv* 2012; **98**: 23–26.
30. Gawande A. *The Checklist Manifesto – How To Get Things Right*. New York: Metropolitan Books; 2009.
31. Haynes AB, Weiser TG, Berry WR *et al*. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 2009; **360**: 491–499.
32. Doran CM, Woolley T, Midwinter MJ. Feasibility of using rotational thromboelastometry to assess coagulation status of combat casualties in a deployed setting. *J Trauma* 2010; **69(Suppl 1)**: S40–S48.
33. Doughty HA, Woolley T, Thomas GO. Massive transfusion. *J R Army Med Corps* 2011; **157(3 Suppl 1)**: S277–S283.

2.3 Commenting on: Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan. Arul S, Pugh H, Mercer SJ, Midwinter M *Annals of The Royal College of Surgeons of England* 2015*;* 97: 262-268

2.3.1 Why this paper was written?

'WHO surgical safety checklist' was launched in 2009 (83) in an attempt to reduce patient safety errors and in particular 'Never Events' (84). Examples of 'Never Events' include the wrong surgery being carried out on a patient or surgery carried out on the wrong site. The checklist itself comes in three parts; a sign in (a check prior to induction of anaesthesia), a 'time out' (a check prior to actually starting the surgery) and a 'sign out' (a check at the end of the surgery). Despite being reported to save lives (85) one of the limitations of the 'WHO Checklist' itself, is that it is time consuming and when treating patients with complex trauma every second counts. As a group of UK-DMS Consultants who had recently deployed to Iraq and Afghanistan, we felt that a shorter alternative should be suggested and piloted for time critical patients who had been involved in complex trauma. Following a discussion paper (14) where the 'Trauma WHO' was suggested and the elements of the checklist chosen explained, we tested the checklist in a deployed field hospital in Camp Bastion (42). This original research article tests the resulting proposed 'Trauma WHO' checklist in a Military Hospital involved in an active conflict.

2.3.2 What was known at the time?

The original 'Trauma WHO' (14) consisted of four components

2.3.2.1 The Command Huddle

The team leader processes information from the patient handover from the pre-hospital team, the primary survey and any initial investigations that have taken place. This is part of the 'gathering evidence' phase or stage one of situational awareness (43) (Figure 1.4). With a sick patient, decisions are time critical and require a senior robust decision (86). The options for

patient treatment will be (but not exclusively) to remain in the trauma bay for further resuscitation, transfer to the CT scanner often for a full body scan (pan-CT), transfer to the operating theatre, critical care or a designated trauma ward. The decision-making process is aided by a senior discussion between the surgeons, anaesthetist and the team leader. The futility of continuing treatment is also considered at this time.

2.3.2.2 The Snap Brief

This stage is a final rapid check before any surgery begins

- The Surgeon confirms
  - The correct patient is present
  - The clinical and imaging findings
  - The surgical plan
- The Anaesthetist states
  - The patient's temperature
  - Blood pressure
  - Blood given so far
  - Blood gas results (particularly the pH and the base excess)
  - Clotting (near point testing e.g. RoTEM & other issues)
  - Confirms antibiotics given
  - Tranexamic Acid given
  - Blood available
- The time of the start of the procedure should be recorded on a whiteboard in the operating theatre

2.3.2.3 Sit Reps

The situation can change rapidly during damage control surgery. The sit-reps or situational update allows all team members to maintain situational awareness. This process usually occurs ever 10-30 minutes, led by anaesthetics and should be quick and inform all members of the team of the patient's status. The initial acronym was TBCS

- **T** Time since the start of the procedure. Temperature
- **B** Blood Pressure, Blood volume given so far, Blood gases
- **C** Clotting (i.e. RoTEM results)
- **S** Surgical progress and plan

This was then later changed after testing on several military exercises to STACK (87)

- **S** Systolic Blood Pressure

- **T** Temperature
- **A** Acidosis
- **C** Coagulation
- **K** Kit (Including blood products used)

2.3.2.4 The sign out and debrief

At the end of the operation a sign-out is essential for both the surgeon and the anaesthetist to summarise the patient's injuries, what procedure has been performed and what has been left untreated. This should ideally be done in the presence of the accepting team (probably from critical care). A 'hot' debrief should be done immediately after the sign-out as the team will rapidly disperse.

2.3.3 What the paper contributed to the 'global' clinical community

The 'Trauma WHO' has now been adopted by the UK-DMS and is used in the training of deployed hospital teams and has been used successfully on other recent deployments. UK-DMS personnel are embedded in the National Health Service and as with many of the other advances from recent conflicts (4) this concept is being translated into NHS trauma teams. At my own hospital, Liverpool University Hospitals NHS Foundation Trust, the concept of 'sit-reps' is firmly embedded into Damage Control Surgery (88) and has led to a culture change in the way that information is exchanged in the operating theatre. This is true for other UK-DMS colleagues who work in major trauma centres in England, and has been described in damage control surgery for sick neonates at Birmingham Children's Hospital (89). During this observational study, 'Trauma WHO' with particular focus on 'sit-reps' was encouraged to enhance communication within the operating theatre team has proved useful in 27 cases between 2010-2017.

2.3.4 Where are we now?

The concept of 'The Trauma WHO' (14) was described in 2012 in an attempt to improve the communication within the complex trauma team. Training on the importance of human factors in complex trauma teams was introduced into the Military Operational Surgical Training Course (86) in 2010 as lectures, workshops and a fully immersive high-fidelity simulation involving the whole trauma team. Following this project the 'sit-rep' stage was modified to STACK (87) as described above and 'The Trauma WHO' has now been formally adopted by the UK-Defence Medical Services. Since Operation HERRICK (Afghanistan) there have been subsequent UK-DMS deployments, Operation GRITROCK (Ebola, West Africa) (90) and Operation TRENTON (South Sudan) (91) and 'The Trauma WHO' has been included in training and used during deployment. As described above, adoption of the 'Trauma WHO' has been predominately where there have been local champions, particularly with clinicians working in the Defence Medical Services. In addition to my own trust there has been a publication from Birmingham Children's Hospital(89) that is described above. In addition to advances in surgical and anaesthetic techniques the year-on-year improvement in survival during both the recent Iraq and Afghanistan conflicts (5) have been thought to be due to improvements in human factors (92) of which the 'Trauma WHO' is certainly a contributor.

2.3.5 Reflections on methodology

Prior to deployment, all theatre staff attended the Military Operational Surgical Training Course (MOST Course) (13) and the Hospital Exercise (12) where they were formally taught about 'The Trauma WHO' and this was practiced during high-fidelity simulation scenarios. On arrival in Afghanistan, theatre staff were reminded about 'The Trauma WHO' and posters were available on the walls of the operating theatre complex. A standardized confidential questionnaire was developed with the help of a psychologist with experience in human factors (Professor Rhona Flin from the University of Aberdeen and original author of the ANTS project (34)) was used to investigate theatre staff attitudes to communication during the management of major trauma. This questionnaire included 12 questions as well as a visual analogue scoring

system and was used to get information on all patients who required damage control surgery and record the reactions of all members of the team associated with the case. There was the opportunity to record comments in free text to allow staff to express their personal opinions.

The following questions were asked

- At the start, were you aware of the patient's injuries?
- At the start of the operation, did you understand the surgical plan?
- Did you know what was required of you at the beginning of the case?

During the case

- Were there regular updates during the case?
- Were changes or problems during the case communicated effectively to the entire team?
- Did you feel that you knew what was happening during the case?
- Did you know what was required of you as the case progressed?

Communication

- Did the team work effectively throughout the case?
- Was there good communication during the operation?
- Did you feel regular sit-reps helped to improve communication?
- Did you feel that you could communicate freely during the case?
- Were regular sit-reps helpful?

In total, 20 different operations including patients with blast or gun-shot wound injuries were studied in a 30-day period during September 2012. Responses from 115 members of staff were collected the composition of which were 30 surgeons, 23 anaesthetists, 18 operating department practitioners, 18 scrub nurses and 26 from other members of staff (such as runners and transfusion staff). Overall, 88% of the theatre staff either agreed or strongly agreed that they were aware of the injuries at the beginning of the case, 91% said there were regular updates during the case and 99% understood what was required of them as the case progressed. Teamwork was found to be effective by 93% of staff members and the same proportion believed there was good communication throughout the case. Over two-thirds (69%) felt that regular sit-reps contributed to improved communication with only 10% feeling that they could become annoying or unhelpful.

Limitations to this study included the following

- This project took place only during one time period (September 2012) and as such only took input from one field hospital unit in the Defence Medical Services. In the entire period of Operation HERRICK, the Role 3 Field Hospital in Camp Bastion was led by regular and reserve units from a wide background of individual experiences.
- Using just one hospital unit could have incorporated bias into the findings, particularly as this was the hospital unit where one of the researchers was posted.
- The project was limited to 30 days and only 20 operations and as there were 2,792 UK military casualties sustaining 14,252 separate injuries during the period in both Iraq and Afghanistan 1 January 2003 to 31 December 2012 (5) this accounts for a minor fraction of cases seen.
- We only used one form of investigation (a questionnaire). Further information may have been obtained had we used other methodology such as a focus group or semi-structured interviews
- These limitations were as a result of a study team member being required to be present in Camp Bastion in Afghanistan to conduct the study.

Positive points from the methodology include the following

- The methodology engaged a wide range of the multidisciplinary team and this was important as the communication tool being investigated (The Trauma WHO) was designed to improve communication throughout the trauma team and in the operating theatre.

2.3.6 Contribution of the Paper to Clinical Practice and what It says about me as a Researcher?

This article was published in 2015 in the *Annals of The Royal College of Surgeons of England* with an impact factor of 1.268. This journal was chosen as it is predominately read by surgeons working 'on the shop floor' who would be dealing with patients with complex injuries. The article has been cited 16 times and has an Almetric Attention score of 2 based on comments on social media (Twitter, 3 comments and 34 readers on Mendeley). I have used this publication to develop the following articles

- Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. Human Factors in Preventing Complications in Anaesthesia. *Anaesthesia* 2018; 73(S1): 12-24
- Mercer SJ, Khan M, Scott T, Matthews J, Henning D, Stapley S. Human Factors on Contingency Operations. *Journal of the Royal Army Medical Corps* 2017: 163; 78-83
- Schofield SL, Welfare E, Mercer SJ. In Situ Simulation. *Trauma* 2018; 20: 281-288
- Mercer SJ Using full immersive simulation to prepare trauma teams to work in a major trauma centre. *Trauma* 2017: 19: 277-285

- Nevins EJ, Bird NTE, Malik HZ, Mercer SJ, Shahzad K, Lunevicius R, Taylor JV, Misra N. A systematic review of 3251 emergency department thoracotomies: is it time for a national database? *European Journal of Trauma and Emergency Surgery* 2018; doi.org/10.1007/s00068-018-0982-z
- Mercer SJ. Human Factors in Ballistic Trauma in Ballistic Trauma. A Practical Guide. Fourth Edition. Editors Breeze MJ, Penn-Barwell JG, Keene D, O'Reilly D, Jeyanathan J, Mahoney PF. Chapter 22. Pg 347-356. Springer, 2017
- Mercer SJ. The trauma team and initial management of the critically injured patient (Chapter 4). In: *Trauma and Combat Critical Care in Clinical Practice* Ed. Hutchings S. Springer; 1st Edition (10 October 2016)

The articles listed in Table 2.3 have also cited this publication (I have only listed articles in English)

Table 2.3. Publications citing Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan. Arul S, Pugh H, Mercer SJ, Midwinter M *Annals of The Royal College of Surgeons of England* 2015*;* **97**: 262-268

Paper	Summary
Arul GS, Pugh HEJ, Kluth MJ and Bromiley M. Common goals, shared risk and a just culture: human factors lessons from the front line. *Journal of the Royal Society of Medicine* 2017; 110: 93–97	An opinion paper from my two colleagues following on from presentations at the Royal Society of Medicine. They described that there was a statistically significant improvement in survival of casualties as the conflicts in Iraq and Afghanistan continued with an estimated 265 casualties surviving potentially fatal injuries from the start of the conflict and injuries that would probably have been fatal at the start of the conflict and 38 surviving with injures classed as 'unsurvivable' by NHS standards. They described the improvements in care in terms of human factors and three tenets: 'Common Goals, Shared Risk and a Just Culture'. This article goes on to describe the importance of human factors in the management of complex trauma as I have described in this thesis.
Bates P, P Parker P, McFadyen I, Pallister I Demystifying damage control in musculoskeletal trauma. *Annals of The Royal College of Surgeons of England* 2016; 98: 291–294	This paper is a discussion on the concepts of Damage Control Resuscitation and in addition to describing the techniques, it reviews the decision making in terminating an operation and moving the patient to critical care. The decision-making centres around the 'Trauma WHO' that we described in our discussion paper (14) and then tested this research paper. The common huddle, snap brief and sit-reps are also discussed as useful in team centered decision making.
Hicks C, Petrosoniak A.The Human Factor. Optimizing Trauma Team Performance in Dynamic Clinical Environments. *Emerg Med Clin N Am* 36 (2018) 1–17. http://dx.doi.org/10.1016/j.emc.2017.08.003	Review of the importance of Human Factors in Trauma Teams. Our paper is quoted in terms of communication amongst the team.
Slope R, Pope C, Crouch R, Bernthal EMM.	Description of patient journey with the importance of good communication. Also taken from Rowena Slope's PhD Thesis 'Exploration

Military and civilian handover communication in emergency care: how does it differ? ***Journal of Paramedic Practice* 2019; 2** **https://doi.org/10.12968/jpar.2019.11.2.66**	of handover communication in military and NHS emergency care settings'.
Groombridge CJ, Kim Y, Maini A, Smit DV, Fitzgerald MC. Stress and decision-making in resuscitation: A systematic review. Resuscitation 2019; 144: 115-122	This is a systematic review that aimed to identify human factors affecting decision making in challenging or stressful situations. Our article was identified in the literature search. The conclusion was that human factors contribute to decision-making and can be mitigated by tailored stress training and cognitive aids.
Chen S, Yang J, Zhang L, et al **Progress on combat damage control resuscitation/surgery and its application in the Chinese People's Liberation Army** **Journal of Trauma and Acute Care Surgery 2019; 87: 954-960**	This is a description of recent advancements in the care of complex trauma patients in the Chinese People's Liberation Army. Our article is cited with respect to efficient delivery of medical information, and smooth communication as other important factors ensuring the continuum of implementation of DCR/DCS
Arul GS, Singh M, Ali AM, Gee OJ. Damage control surgery in neonates: Lessons learned from the battlefield. Journal of Paediatric Surgery 2019 (in press) **https://doi.org/10.1016/j.jpedsurg.2019.04.001**	This is a description of how the Trauma WHO is useful in civilian practice with a narrative of how it was used for 27 neonates undergoing Damage Control Surgery between 2010-2017.

2.3.7 Where this paper places me with reference to being at the forefront of my area of professional practice.

I am a recognised national speaker in the field of human factors and simulation to train trauma teams. The following invited national and international presentations contained details of 'The Trauma WHO'. These meetings were attended by members of the multi-disciplinary team.

Title: **Simulation for Trauma Training**
Meeting: Trauma Care Conference
Location: Yarnfield Conference Centre,
Date: Stafford 6 March 2019

Title: **Improving Trauma Teams. Understanding Why Teams Don't Work**
Meeting: Cambridge Trauma Conference
Location: Churchill College Cambridge
Date: 28 April 2018

Title: **Human Factors in Complex Trauma**
Meeting: Association of Anaesthetists of Great Britain and Ireland Annual Congress
Location: BT Convention Centre, Liverpool
Date: 28 September 2017

Title: **Training for Trauma**
Meeting: Royal College of Anaesthetists, Updates Meeting
Location: Marriott Hotel, Liverpool
Date: 11 May 2016

Title: **Training the Whole Trauma Team**
Meeting: The Anesthesiology Annual Meeting
Location: San Diego Conference Centre, San Diego, California, US
Date: 27 October 2015

Title: **Training the Whole Trauma Team**
Meeting: Uniformed Services Society of Anesthesiologists/ Association of Veterans' Affairs Anesthesiologists Annual Academic Meeting
Location: Hilton San Diego Bayfront Hotel, San Diego, California, US
Date: 23 October 2015

Title: **Human Factors in Trauma**
Meeting: North West Regional Trauma Meeting
Location: Whiston Hospital
Date: 8 September 2015.

Title: **Testing the Whole Obstetric Team: Lessons from Simulation in Military Medicine**
Meeting: Obstetric Anaesthetists Association Annual Scientific Meeting
Location: Torquay
Date: 21 May 2015.

Title: **Using Simulation to Train Trauma Teams**
Meeting: Trauma Care Conference
Location: Telford
Date: 22 April 2015

Title: **Teamwork and Human Factors. A Military Anaesthesia Perspective**
Meeting: Association of Cardiothoracic Anaesthetists
Location: Manchester
Date: 27 March 2015

Title: **Lessons from conflict – the importance of training and research**
Meeting: AAGBI Annual Conference
Location: Harrogate
Date: 17 September 2014

Title: **Safety Through Team Working - Lessons Learnt from Anaesthesia in the Military**
Meeting: 5th NWAC World Anaesthesia Convention
Location: Vienna
Date: 3 May 2014

Title: **Training for Trauma,**
Meeting: Current Concepts Meeting
Location: Royal College of Anaesthetists, London
Date: 10 October 2013

Title: **Human Factors in Trauma Teams**
Meeting: West Midlands Anaesthetic Society Summer Meeting
Location: National Motorcycle Museum, Birmingham
Date: 14 June 2013

Title: **Human Factors in Trauma Teams**
Meeting: Royal College of Anaesthetists Updates Meeting
Location: Royal College of Anaesthetists, Liverpool
Date: 10 December 2012

Title: **Trauma Update**
Meeting: Liverpool Society of Anaesthetists
Location: Liverpool Medical Institute
Date: 16 November 2012

Title: **Preparing Civilian Trauma Teams**
Meeting: Association for Simulated Practice in Healthcare
Location: Kassam Stadium, Oxford
Date: 8 November 2012

Title: **Clinical care - Crew Resource Management**
Meeting: Disaster planning and management - are we prepared?
Location: Royal Society of Medicine
Date: 13 April 2012

Title: **Human Factors in Damage Control Resuscitation**
Meeting: Association of Anaesthetists of Great Britain & Ireland Updates Meeting
Location: Liner Hotel Liverpool
Date: 24 February 2012

The knowledge from this paper was incorporated into the Military Operational Surgical Training Course (13) and also the Hospital Exercise (12) which are courses for the deploying trauma teams. Training was undertaken as a multidisciplinary team with good feedback.

Research and Knowledge Exchange
Graduate School
Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for each publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries Mercer SJ, Lewis SE, Wilson SJ, Groom P, Mahoney PF. *Journal of the Royal Army Medical Corps* 2010; **156**: S357-362

3. Candidate's contribution to the research output
(State nature and approximate percentage contribution of each author)

PF Mahoney (20%), original idea, supervisor, revision of manuscript. SJ Mercer (50%) literature review, review of JTTR database and survey of DMS anaesthetists, 1st draft of manuscript. SE Lewis (20%) review of literature and subsequent reviews of manuscript. SJ Wilson (5%) subsequent manuscript reviews, P Groom (5%) subsequent manuscript reviews.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
PF Mahoney	P Mahoney 5/June/19	profpfm62@me.com
SE Lewis	S. Lewis 7/6/19	stephenedward.lewis@nhs.net
P Groom	[redacted]	petergroomx@yahoo.com
SJ Wilson	8 JUNE 2019	stevewilson2@nhs.net

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	

	(Director of Studies/Advisor)		
6. Signature of Faculty Research Degrees Administrator			
Signature:		Date:	
	(Faculty Research Degrees Administrator)		

Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries

SJ Mercer[1], SE Lewis[2], SJ Wilson[3], P Groom[4], PF Mahoney[5],

[1]Specialist Registrar in Anaesthesia & Critical Care, University Hospital Aintree NHS Foundation Trust, Merseyside; [2]Specialist Registrar in Anaesthesia & Critical Care, St George's Healthcare NHS Trust, London; [3]Consultant Anaesthetist, James Paget University Hospital Foundation NHS Trust, Great Yarmouth; [4]Consultant Anaesthetist, University Hospital Aintree NHS Foundation Trust, Merseyside; [5]Defence Professor Anaesthesia and Critical Care, Royal Centre for Defence Medicine Birmingham Research Park, Vincent Drive, Birmingham

Abstract

Anaesthetists in the Defence Medical Services (DMS) are currently dealing with casualties who have an increased prevalence of injuries due to blast, fragmentation and gunshot wounds. Despite guidelines already existing for unanticipated difficult tracheal intubation these have been designed for a civilian population and might not be relevant for the anticipated difficult airway experienced in the deployed field hospital. In order to establish an overview of current practice, three methods of investigation were undertaken; a literature review, a survey of DMS Anaesthetists and a search of the UK Joint Theatre Trauma Database. Results are discussed in terms of anatomical site, bleeding in the airway, facial distortion, patient positioning and an anaesthetic approach. There are certain key principles that should be considered in all cases and these are considered. Potential pitfalls are discussed and our initial proposed guidelines for use in the deployed field hospital are presented.

Introduction

Combat trauma airway management is distinctive because of the increased prevalence of penetrating airway injuries [1]. The majority of UK military deployed trauma consists of blast/fragmentation injuries (53.8%) and gunshot wounds (GSW) (29.9%), in contrast to National Health Service (NHS) trauma where the bulk is blunt airway injury due to motor vehicle collisions [2]. Penetrating injuries are often dramatic with severe disruption of both soft tissue and bone [3], and airway injury is likely in ballistic and penetrating injury to the face and neck. The proximity of the carotid vessels means that penetrating carotid injury may impact airway patency. Consequently the team dealing with such injuries need to consider the likely fragment /projectile trajectory and potential airway effects.

UK Defence Medical Services (DMS) anaesthetists spend the majority of their clinical practice working with civilian patients in the NHS and will generally deploy on military operations every six to 18 months. Not only does the deployed environment have a different case mix, but clinicians are also required to use what may be unfamiliar equipment and Standard Operating Procedures (SOPs). SOP's have been developed for management of the difficult airway by the American Society of Anesthesiologists (ASA) [4], and for the unanticipated difficult airway by the Difficult Airway Society (DAS) [5]. Both protocols were designed to deal with a civilian patient population in the setting of a general hospital and do not reflect the circumstances currently encountered in the deployed military environment. Although the management of anticipated difficult airway has recently been evaluated to some extent in a civilian setting [6], we felt the unusual nature of penetrating airway injury necessitated its own SOP for use in the deployed field hospital. It is hoped that this will allow anaesthetists to improve their non-technical skills or human factors [7] in a clinical environment that has recently be identified as exceptional by the Healthcare Commission [8].

There is a lack of literature reporting the anaesthetic management of penetrating neck injuries [9,10] with manuscripts often concentrating on surgical management [11]. Currently, there is no consensus amongst the anaesthetic community on the management of casualties with penetrating airway injuries [12] and much variability has been described [11]. We reviewed the current literature, the experience of previously deployed UK DMS anaesthetists as well as documented experience from the UK Joint Theatre Trauma Registry (JTTR) [2] and present our initial guidelines.

Corresponding Author: Surgeon Lieutenant Commander Simon J Mercer Royal Navy, 22 The Knowles, Blundellsands Road West, Crosby, Liverpool, L23 6AB.
Mobile number: 07970153168. Email: simonjmercer@hotmail.com

Methods

In order to establish a complete overview of current practice, three separate methods of investigation were undertaken.

Literature Review

The databases and search terms used to identify papers published after 1995 are summarized in Table 1. Two of the authors (SEL/SJM) evaluated each paper for relevance to the anaesthetic management of penetrating head and neck injuries and summarized any case reports.

Survey of DMS Anaesthetists

All 185 DMS Anaesthetists whose details were held on the Defence Consultant Advisor (DCA) database were contacted by e-mail on 23 November 2009. The details of any cases of blast or ballistic airway injury that they had treated were requested. This email was repeated on 23 January 2010. All cases were collated in tabular form.

Search of the UK Joint Theatre Trauma Registry (JTTR)

The UK JTTR has already been described in this journal [13] and is maintained by the Academic Department of Military Emergency Medicine at the Royal Centre for Defence Medicine. Essentially this registry contains continuous data from 2003 for

Database	Search Terms
Pubmed [14] Sciencedirect [15] Google Scholar[16]	Ballistic airway Blast airway Penetrating airway Laceration airway Fragmentation airway Gunshot airway Knife airway.
AMED BNI EMBASE HMIC MEDLINE PsycINFO CINAHL HEALTH BUSINESS ELITE	Ballistic-airway Ballistic AND airway Blast-airway Blast AND airway Penetrating-airway Penetrating AND airway Laceration-airway Laceration AND airway Fragmentation-airway Fragmentation AND airway Gunshot AND airway Knife AND airway

Table 1. Literature Search Terms

all casualties who trigger a trauma team activation in either the deployed field hospital or the Primary Casualty Receiving Facility afloat. Over 3000 records were interrogated for the search terms listed in Table 2. Cases identified by this search were analyzed by one of the authors (SJM) and those consisting of casualties with blast and ballistic head and neck trauma were recorded.

Search Term
Casualty Reference Numbers
Gender
Major Trauma
UK Military
Survivors
Blast Injury or Ballistic Injury
New Injury Severity Score (NISS) >16
Airway Interventions
Mechanism of Injury
Brief Incident History
Injuries
Information from free text boxes.

Table 2. Search terms used to identify cases in JTTR

Results

The literature review revealed 51 papers that were considered relevant to this study; 23 were civilian case reports and three contained military case reports. There were 17 case reports submitted by DMS Anaesthetists and the cause of injury in all cases was either GSW or Improvised Explosive Device (IED). Over 3000 were searched on the JTTR and 19 were identified of soldiers with penetrating head and neck injury. These injuries were either caused by blast (from IED, mine, mortar or rocket propelled grenade) or were due to GSW. Common themes from all three areas of investigation are summarized in headings below.

Penetrating injury though the mouth

Case reports included projectiles or objects transfixing facial structures and interfering with mouth opening. Examples included transfixion through the floor of the mouth with a bamboo cane [17], penetration of the mouth floor with a nail [18], a spear gun shaft penetrating the floor of the mouth [19] and a crossbow arrow entering under the chin and passing through the tongue, nasal cavity and between the frontal lobes [20]. Methods of management included awake fibreoptic intubation (AFOI) [17-20] rapid sequence induction of anaesthesia (RSI) [22,23] and surgical tracheostomy following failure of AFOI [19].

Injuries to the Face

Two articles summarized case series of GSW to the face from Level 1 Trauma Centres in the USA [23] and South Africa [24]. Of 73 patients in the USA case series, 36 underwent AFOI, 30 were conventionally intubated and seven had a cricothyroidotomy performed. In the South African case series there were 28 emergency orotracheal intubations (18 of which were performed in the prehospital phase), two cricothyroidotomies and six tracheostomies. The DMS survey revealed five case reports of soldiers with facial injuries as a result of IED blasts and four of these underwent uneventful RSI (one had a surgical tracheostomy performed in the prehospital phase). There were 4 case reports of GSW to the face of which two had RSI, one had a cricothyroidotomy and the other had an emergency surgical tracheostomy. The JTTR search contained three casualties who had undergone blast injuries to the face, two of which were managed by RSI and one who underwent cricothyroidotomy in the prehospital phase.

Laceration to the neck

There were several case reports of isolated neck laceration injuries [25,26] and an open laryngeal injury in a patient with multiple injuries [27]. Management included a pre-hospital cricothyroidotomy [27], surgical tracheostomy [25] and intubation directly though the defect [26,27]. There was a case report concerning a crush injury to the chest resulting in complete tracheal transection. This was managed with a surgical tracheostomy as the patient developed subcutaneous emphysema in the neck and anterior chest following orotracheal intubation [28].

Penetrating Neck Injuries

Case reports included a bullet fragment in the supraglottic region [29] and GSWs [30-32] to the neck. These were managed by orotracheal intubation [30], inhalational induction of anaesthesia [31], flexible bronchoscopy [32] and use of a light wand following failure of direct laryngoscopy [29]. Case series of penetrating neck injuries from US Trauma Centres [33,34] reported a combination of techniques including RSI, surgical tracheostomy, AFOI and orotracheal intubation without paralysis in comatose patients. A Canadian case series [11] also reported the use of AFOI and RSI. Another case series from a Level 1 Trauma Centre in the USA [35] reviewed the airway management of 89 patients with penetrating neck injuries who had undergone blind nasal intubation. The authors concluded that this technique was a valuable tool for the management of patients with penetrating neck trauma. There were three case reports in the literature of soldiers who sustained penetrating neck injuries as a result of improvised explosive devices (IEDs). Management included emergency cricothyroidotomy following failed orotracheal intubation [36],

surgical tracheostomy in the operating theatre following failed orotracheal intubation [37] and orotracheal intubation followed by surgical tracheostomy [38].

The DMS survey reported several cases of penetrating neck injury these included:

- A GSW causing damage to the posterior tracheal wall associated with bleeding into the airway, managed with a RSI.
- An IED blast to the face and neck, managed by transferring the patient to theatre in the prone position to maintain their airway. RSI was performed as soon as the patient was turned supine. A trauma surgeon was ready to perform a surgical airway if needed.
- A penetrating neck injury, managed by orotracheal intubation following gaseous induction using the Tri-service Anaesthetic Apparatus [39] with two Oxford Miniature Vaporizers filled with Sevoflurane.
- A GSW through the larynx was managed by direct intubation through the defect and then a subsequent surgical tracheostomy. A GSW injury disrupting the cricoid ring was managed with RSI.

Results from the JTTR included four cases of penetrating neck injury of which one was managed by RSI. In addition to this there were seven case reports of injury to the trachea and larynx. Of these, four patients underwent RSI, (one of which failed and required cricothyroidotomy), one received a primary surgical tracheostomy and one had an endotracheal tube placed directly through the tracheal defect.

Carotid Artery Injury

One case reported the use of AFOI to manage a penetrating neck injury tearing the common carotid artery that was causing a rapidly expanding haematoma [40]. Another case report describing a patient with neck compression due to strangulation with a chain and this was managed by conventional orotracheal intubation [41]. There was also a case report of a patient who sustained internal and external common arteries injuries following a laceration from a flying metal sheet, this was managed by intubation into the perforation of larynx [42]. A case report from the DMS survey described a casualty with a GSW to the neck associated with a laceration to the carotid artery resulting in respiratory distress and this was managed by inhalational induction of anaesthesia. There were an additional three cases of penetrating neck injury on the JTTR database (all as a result of IED blast) resulting in laceration of the carotid artery. Anaesthetic details were entered for only one of these cases, which was managed with an RSI.

Discussion

There are multiple potential approaches to the airway management of casualties penetrating injuries [43] and although the incidence is low, we felt that it was important to develop guidelines to allow planning and anticipation of these cases prior to deployment as an aide memoire. The anaesthetist may wish to base their decision making process on the clinical scenario rather than a preset algorithm taking into account their own skills and equipment available [11]. It has already been commented that most case series only contain small numbers of patients and that the injuries are diverse, meaning a didactic treatment algorithm would be unhelpful [12]. Our three different methods of investigating the anaesthetic management of penetrating airway injury resulted in a wide variety of opinions and our conclusions are enumerated below.

The anatomical site of the injury

This is a crucial consideration as penetrating neck wounds are best approached on a zonal basis [44]

Zone I - between the clavicles and the cricoid cartilage.

Zone II - between the inferior margin of the cricoid cartilage and the angle of the mandible

Zone III - between the angle of the mandible and the base of the skull.

Reference to a zone allows the prediction of potential injuries and so the potential for urgent airway management problems [12]. It should be noted that wounds in the anterior and lateral aspects of the neck compromise the airway more often than those in the posterior region [12]. Once the zone(s) involved have been identified the clinician should then consider the presence of injury to the airway's lumen (with associated blood and debris), injury within the airways wall itself or injury outside the wall (e.g. expanding haematoma or surgical emphysema). Optimal intubation conditions may be difficult to achieve and injuries may compromise positive pressure ventilation with bag-valve-mask devices [11]. Not all patients will be *in extremis* however and there may be time to consider additional investigations to characterise the injury. CT is considered the first-line investigation in stable patients with penetrating neck injuries [45] to identify the location, nature and extent of any airway injury.

Airway bleeding/facial distortion and patient positioning

Blood and debris may be soiling the airway and if the casualty is maintaining their airway satisfactorily they do not require immediate airway intervention apart from a jaw thrust. They should be allowed to adopt their most comfortable position. Lateral, sitting and prone positions have all be described in case reports and the importance of this must be reinforced during patient handover.

Anaesthetic approaches to penetrating airway injury

The principle clinical features mandating early tracheal intubation are acute or worsening respiratory distress, an airway that is compromised by blood and secretions, extensive surgical emphysema, tracheal deviation by haematoma and a decreasing level of consciousness [46]. Although anaesthetists perform endotracheal intubation routinely, it should be approached with great caution in a patient with a penetrating airway injury [47].

Direct Laryngoscopy/ Rapid Sequence Induction (RSI)

It is important that anaesthetists are aware that despite the laryngeal inlet appearing intact, there may be a tracheal tear present below this and placing an endotracheal tube under direct laryngoscopic vision could lead to the tip passing through the defect. This may go unrecognized and risks airway obstruction, pneumomediastinum and the creation of a false passage [47] as this is in effect a 'blind technique', which may completely disrupt the larynx. The incidence of these phenomena is unknown but is most likely lethal and difficult to reverse even with an emergency surgical airway (especially if gross surgical emphysema has been created) [12]. Others recommend an 'awake look' under topical anaesthesia but this will obviously not indicate if there are any injuries distal to the vocal cords [11].

Some authors hold that RSI should be the default method of airway control [48]. Evidence is available to suggest that it is safe [49] and has a high success rate [33,34,50]. Despite this, there are others who argue against RSI in certain cases [36,37], where the

airway is penetrated below the vocal cords (risking unrecognized misplacement of the ETT). It is also not recommended in cases of near or total airway transection, where paralysis will abolish the supportive muscle tone, which may be all that is holding the airway together [11,51]. For these reasons, some authors actively support the casualty maintaining spontaneous ventilation at all costs [47]. Current UK anaesthetic practice includes the use of cricoid pressure [52] during an RSI but this may distort the airway, change the anaesthetist's view and result in a more difficult airway [47,53].

Blind Nasal Intubation

The consensus of opinion is that blind intubation methods including blind nasotracheal intubation should not be used in patients with penetrating neck injury because further injury or complete airway obstruction may be induced [54]. A single paper reviewing a case series of patients successfully managed with blind nasotracheal intubation has challenged this advice [35]. As this technique is rarely taught in UK hospitals, we would discourage its use by clinicians for whom it is not part of their regular practice. It also requires extension at of the upper cervical spine while the lower cervical spine is extended, as part of the technique, which may risk neurological injury in the unstable cervical spine in trauma.

Fiberoptic Intubation

AFOI is the gold standard for safely securing the airway in a casualty with a traumatic airway injury. This technique allows the lumen of the airway to be identified by direct vision throughout the intubating process and allows the anaesthetist to be confident about siting the endotracheal tube (ETT) distal to any visualized tear.

This technique depends on availability of a fiberscope, the co-operation of the patient [47,55] and the skills of the operator. Another confounding factor to this method of securing the airway is that any foreign bodies or blood will hinder the use of the fiberscope [47] although in skilled hands it has proved very effective [17-20, 23,24,40]. Difficulties regarding AFOI in the field hospital also arise from the sterilization aspect of the fiberscope, however recently disposable versions have been developed, but are yet to be evaluated in this setting.

Surgical Airway

A case could be made to consider surgical airway as the first choice intervention for laryngeal injuries [47,56] as it is done under direct vision reducing the potential for worsening an injury by misplacement the endotracheal tube. Both cricothyroidotomy and tracheostomy have been described as safe techniques to perform in an awake, spontaneously ventilating patient with local anaesthetic infiltration [47]. Cricothyroidotomy itself has further been described as a safe, rapid technique of obtaining an airway in an emergency setting [57]. Tracheostomy should be performed at least one tracheal ring below the injury to avoid complications [12]. Whenever a difficult intubation is suspected it is advisable to have the patient's neck prepared and the surgeon ready to perform a surgical airway [47]. The anaesthetist should be mindful that the rapid creation of a surgical airway might be a difficult task for the surgeon, particularly if there is overlying haematoma or other gross anatomical disruption.

Recommendations

Despite the variety of anaesthetic management strategies present in the literature, there are certain key principles we believe should be considered in all cases. These are listed in Table 3. Human factors play an important role in ensuring that individuals in a clinical team perform to the highest standard [58]. We believe that the principles of Anaesthesia Crisis Resource Management (ACRM) [59] are crucial to ensuring the best possible outcome when faced with a patient with severe blast or ballistic injuries.

Monitor patient with full AAGBI standard monitoring [60] (especially $ETCO_2$)
Preoxygenation (even in patients with marginal functional reserve [43,47,54])
Airway optimization
- If conscious allow patient to adopt most comfortable position [46].
- If unconscious use jaw thrust

Consider the urgency with which a secure airway is required
Consider the site of injury
Availability of suction (preferably two devices)

Table 3. Key principles to consider for all casualties with a penetrating airway injury

Potential Pitfalls

The literature review and DMS Anaesthetists experience and JTTR search have enabled us to suggest certain pitfalls when dealing with patients with penetrating airway injuries. These should be considered when constructing a plan of securing the airway and are listed in Table 4.

Ventilation: Positive pressure ventilation risks enlarging tears and causing surgical emphysema
- **Try to preserve spontaneous ventilation prior to intubation**
- Use bag-valve-mask ventilation is a last resort
- Avoid LMA in injuries distal to cords
- Avoid transtracheal jet ventilation

Intubation: Blind placement of the tube risks the tip passing through the defect and lying outside the airway and is only avoided by fibreoptic intubation or a surgical airway.

Intubation: Endotracheal intubation should be approached with caution
- **Avoid oral intubation when the injury is distal to the vocal cords**
- **Avoid blind nasal intubation**
- **Fibreoptic intubation is likely to be difficult/ impossible when there is bleeding into the airway**

Surgical Airway
- Is potentially extremely difficult in face of subcutaneous emphysema or an expanding haematoma (direct laryngoscopy is also likely to also be difficult).

Drugs: Avoid muscle relaxants in near/complete airway transection
- **Muscle tone may be important for airway integrity**

Table 4 Potential Pitfalls to consider when drawing up plans to secure the airway.

In proposing initial guidelines for DMS anaesthetists, we have been strongly influenced by the comments made in the review article by Abernathy [47] regarding the placing of an endotracheal tube when a distal airway injury has not been excluded. In such cases a primary surgical airway may be the most appropriate plan [43]. Whether it is the anaesthetist or the trauma surgeon who performs this will be decided by the skills and experience of the individuals within the team.

Our initial guidelines based on site of injury are summarized in Table 5. We anticipate that this preliminary work will now lead to further studies to develop guidelines and training systems. We also hope to work with national bodies such as the Difficult Airway Society to further develop our guidelines.

Zone I injury
- Consider direct intubation through a large defect
- Consider tracheostomy
- Consider a thoracotomy in complete tracheal transection [62]

Zone II injury
- Consider a CT scan to exclude distal airway injury
  - (Provided that there is no immediate impending obstruction of the airway).
- Consider oral intubation by RSI for injuries proximal to the larynx
- Consider fibreoptic intubation for injuries distal to the larynx
- Consider a surgical airway for injuries distal to the larynx

Zone III injury
- Consider oral intubation by RSI for small defects
- Consider surgical airway for gross disruption.

For any large airway defect
- Consider direct intubation through the defect

Table 5 Suggested Guidelines for the Airway Management of Penetrating Airway Injury

Acknowledgements

The authors would like to thank Major Suzi Robinson QARANC and her team at the Royal Centre for Defence Medicine for their help performing the search of the Joint Theatre Trauma Database and Mr. Michael Rowe, Defence Librarian for his help with the Literature Search.

References

1. Adams BD, Cuniowski PA, Muck A, De Lorenzo RA. Registry of Emergency Airways Arriving at Combat Hospitals. J Trauma 2008; **64**:1548–1554.
2. Hodgetts TJ, Davies S, Russell R, McLeod J. Benchmarking the UK Military Deployed Trauma System. JR Army Med Corps 2007; **153**: 237-238
3. Pandit JJ, Popat M. Difficult Airway Management in Maxillofacial Trauma. Semin Anesth Perio M 2001; **20**: 144-153
4. An Updated Report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Practice Guidelines for Management of the Difficult Airway. Anesthesiology 2003; **98**:1269-77
5. Henderson JJ, Popat MT, Latto PI, Pearce AC. Difficult Airway Society Guidelines for Management of the Unanticipated Difficult Intubation. Anaesthesia 2004; **59**: 675–94.
6. Aintree Difficult Airway Management. Available at: http://adam.liv.ac.uk [accessed 8 June 2010]
7. Mercer SJ, Whittle CL, Mahoney PF. Human Factors in Defence Anaesthesia – Lessons from the Battlefield. Br J Anaesth 2010 **105**: 9-20
8. Health Care Commission. Defence Medical Services : A Review of the Clinical Governance of the Defence Medical Services in the UK and Overseas. Commission for Healthcare Audit and Inspection. March 2009. Available at: http://www.nhs.uk/Defencemedicine/Documents/Defence_Medical_Services_review%5B1%5D.pdf. [accessed 26 February 2010]
9. Kummer C, Netto FS, Rizoli S, Yee D. A review of traumatic airway injuries: Potential implications for airway assessment and management. Injury 2007: **38**; 27-33
10. Brywczynski JJ, Barrett TW, Lyon JA, Cotton BA. Management of penetrating neck injury in the emergency department: a structured literature review. Emerg Med J 2008; 25: 711–715.
11. Tallon JM, Ahmed JM, Sealy B. Airway management in penetrating neck trauma at a Canadian tertiary trauma centre. Can J Emerg Med Care 2007; 9:101-4
12. Desjardins G, Varon AJ. Airway management for penetrating neck injuries: the Miami experience. Resuscitation 2001: **48**; 71–75
13. Smith J, Hodgetts T, Mahoney PF, et al. Trauma Governance in the UK Defence Medical Services. *JR Army Med Corps* 2007; **153**: 239-242.
14. PubMed. US National Library of Medicine. National Institutes of Health. Available at: http://www.ncbi.nlm.nih.gov/sites/entrez?db=pubmed [accessed 10 June 2010]
15. ScienceDirect. Available at: http://www.sciencedirect.com [accessed 10 June 2010]
16. GoogleScholar. Available at: http://scholar.google.co.uk [accessed 10 June 2010]
17. Ng KFJ, Lo CF. The bamboo skewer: Airway management in a patient with penetrating injury of the floor of mouth. Can J Anaesth 1996; **43**: 1156-1160
18. Dobson GT. Airway management in a patient with a nail-gun injury to the floor of the mouth. Ulster Med J 2000; **69**: 148-51.
19. Ban LH, Leone M, Visintini P, et al. Craniocerebral penetrating injury caused by a spear gun through the mouth: case report. J Neurosurg. 2008; **108**: 1021-3.
20. Joly LM, Oswald AM, Disdet M, Raggueneau JL. Difficult endotracheal intubation as a result of penetrating cranio-facial injury by an arrow. Anesth Analg 2002; **94**: 231-2
21. Incollingo F, Shevchenko Y. Airway management in a child with penetrating pharyngeal wall foreign body injury: a case report. AANA Journal. 2007; **75**: 329-32.
22. Rafique MB, Nesselrode R, de Armendi AJ. Difficult airway due to sprinkler spike in the head. Paediatr Anaesth 2008; **18**: 903-4.
23. Demetriades D, Chahwan S, Gomez H, Falabella A, Velmahos G, Yamashita D. Initial evaluation and management of gunshot wounds to the face. J Trauma 1998; **45**: 39-41
24. Glapa M, Kourie JF, Doll D, Degiannis E. Early management of gunshot injuries to the face in civilian practice. World J Surg 2007; **31**: 2104-10.
25. Ezeanolue BC. Management of the upper airway in severe cut-throat injuries. Afr J Med Med Sci 2001;**30**:233-5.

26. Singh B., Kumar S., Kumar V. Management of complete cricotracheal separation following sharp edge injury. J Anaesthesiol Clin Pharmacol 2004; **20**: 79-82
27. Steinig JP, DeLoach ED, Boyd CR. Transection of the base of the tongue caused by penetrating injury. Am Surgeon 1999; **65**: 133-4.
28. Valerio P, Ivan M, Francisco R, et al. Survival after traumatic complete laryngotracheal transection. Am J of Emerg Med 2008; 26: 837
29. Sahu S, Agarwal A, Rana A, Lata I. Emergency intubation using a light wand in patients with facial trauma. J Emerg Trauma Shock. 2009; **2**: 51-3.
30. Sari M., Baylancicek S., Inanli S. Atypical penetrating laryngeal trauma: A bullet in the larynx. Eur J Emerg Med 2007; **14**: 230-232
31. Young O, Watters K, Sheahan P, Hughes J. Penetrating air gun wound in the neck. Auris Nasus Larynx. 2008; **35**: 426-8.
32. O'Connor JV, Haan JM, Wright JL Spent bullet in the bronchus. Am Surgeon 2006; **72**: 345-6.
33. Mandavia DP, Qualls S, Rokos I. Emergency airway management in penetrating neck injury. Ann Emerg Medicine. 2000; **3**5: 221-5.
34. Grewal H, Rao PM, Mukerji S, Ivatury RR. Management of penetrating laryngotracheal injuries. Head Neck 1995;**17** :494-502
35. Weitzel N, Kendall J, Pons P. Blind nasotracheal intubation for patients with penetrating neck trauma. *J Trauma* 2004; 56: 1097-1101
36. Gallo AC, Adams BD. Emergency battlefield cricothyrotomy complicated by tube occlusion. J Emerg Trauma Shock. 2009; **2**: 54-5.
37. Sharma N, De M, Martin T, Pracy P. Laryngeal reconstruction following shrapnel injury in a British soldier: case report. J Laryngol Otol 2009; **123**: 253-6.
38. Banfield GK, Chowdhury CR, Brookstein R. Penetrating laryngeal injury: two case reports from Bosnia. J Laryngol Otol 1995; **109**: 144-6.
39. Houghton I. The Triservice anaesthetic apparatus. Anaesthesia 1981; **36**: 1094-1108
40. Kotsev S. Airway management in a patient with a vascular injury and rapidly expanding neck haematoma. Eur J Anaesthesiol 2005; **22**: 556-8.
41. Venkatachalam S, Palaniswamy SD, Rangarajan M, Mani K, Palanivelu C. An unusual case of penetrating tracheal ("Cut throat") injury due to chain snatching: The ideal airway management. Indian J Criti Care Med 2007: **11**; 151-154
42. Lin HL, Lin JN, Lin YK, Kuo LC, Lee WC, Chen CW. Damage control in the transection of carotid artery-a case report. Ann Emerg Medicine 2008; **26**: 841
43. Nelson LA. Airway trauma. Int Anesthesiol Clin 2007; **45**: 99–118.
44. Baron BJ. Penetrating and blunt neck trauma. In: Tintinalli JE, Kelen GD, Stapczynski JS, (editors). Emergency Medicine: A Comprehensive Study Guide. 6th Ed, 1590-1595. New York: McGraw-Hill 2004.
45. Inaba K, Munera F, Mckenney M, et al. Prospective evaluation of screening multislice helical computed tomographic angiography in the initial evaluation of penetrating neck injuries. *J Trauma* 2006; 61: 144–9
46. Bowley DM, Robertson SJ, Boffard KD Bhagwanjee S. Resuscitation and anaesthesia for penetrating trauma. Curr Opin Anesthesio 2003; **16**: 165–171
47. Abernathy JH III, Reeves ST Airway catastrophes. Curr Opin Anesthesio 2010; **23**: 41-46
48. Shearer VE, Giesecke AH. Airway management for patients with penetrating neck trauma: a retrospective study. Anesth Analg 1993; **77**: 1135–8.
49. Brywczynski JJ, Barrett TW, Lyon JA, Cotton BA. Management of penetrating neck injury in the emergency department: a structured literature review. Emerg Med J 2008; **25**: 711–715.
50. Eggen JT, Jorden RC. Airway management, penetrating neck trauma. J Emerg Med 1993; **11**: 381–5.
51. Chow JL, Coady MA, Varner J, et al. Management of acute complete tracheal transection caused by nonpenetrating trauma: report of a case and review of the literature. J Cardiothor Vasc An 2004; **18**: 475–478.
52. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia. Lancet. 1961; **19**: 404-6.
53. Landsman I. Cricoid pressure: indications and complications. Paediatr Anaesth 2004; **14**: 43–47
54. Pandit JJ, Popat M. Difficult Airway Management in Maxillofacial Trauma. Semin Anesth 2001; **20**: 144-153
55. Prichayudh S, Pak-art R, Sriussadaporn S, et al. Airway management of penetrating neck injury by large foreign body impalement: Report of a case. Injury Extra 2009, doi:10.1016/j.injury.2009.10.025
56. Schaefer SD. The acute management of external laryngeal trauma. A 27-year experience. Arch Otolaryngol 1992; **118**: 598–604.
57. Salvino CK, Dries D, Gamelli R, Murphy-Macabobby M, Marshall W. Emergency cricothyroidotomy in trauma victims. J Trauma 1993; **34**: 503–5
58. Gawande AA, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. Surgery 2003; **133**: 614–21.
59. Gaba DM, Fish KJ, Howard SK. Crisis management in anesthesiology. New York: Churchill Livingstone, 1994
60. Association of Anaesthetists of Great Britain and Ireland. Recommendations for Standards of Monitoring During Anaesthesia and Recovery. 4th Edition March 2007. Available at: http://www.aagbi.org/publications/guidelines/docs/standardsofmonitoring07.pdf [accessed 01 May 2010]
61. Kendall JL, Anglin D, Demetriades D. Penetrating neck trauma. Emerg Med Clin N Am 1998; **16**: 85-105.

2.4 Commenting on Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries Mercer SJ, Lewis SE, Wilson SJ, Groom P, Mahoney PF. *Journal of the Royal Army Medical Corps* 2010; 156: S357-362

2.4.1 Why this paper was written?

This article was published following research looking into publishing a series of guidelines for deploying anaesthetists from the UK Defence Medical Services. At the time, there was no consensus amongst the anaesthetic community on the management of casualties with penetrating airway injuries despite there being published guidance on the management of the unanticipated difficult intubation (29) that has subsequently now been revised (93). This study looked to examine the current literature on the management of airway injuries in trauma and analyse recent experience from operations in Iraq (Operation TELIC) and Afghanistan (Operation HERRICK). The latter was performed by a questionnaire of all serving UK-DMS anaesthetists and by reviewing patients who had been captured on the Joint Theatre Trauma Registry (JTTR). It was hoped that once written, then a series of guidelines would be published and then incorporated into training on the Military Operational Surgical Training Course (86). This would serve to prepare Consultant Anaesthetists working primarily in a civilian environment to deploy to a conflict zone with casualties suffering with primarily penetrating trauma.

2.4.2 What was known at the time?

Prior to conducting this research, it was appreciated that experience of penetrating neck injuries in recent conflicts was rare, although not formally quantified. It was agreed by the Academic Department of Military Anaesthesia Pain and Critical Care that a review of this topic be conducted so that the latest evidence and experience could be incorporated into the Military Operational Surgical Training Course to prepare UK-DMS Anaesthetists about to deploy.

In reality, very little was formally agreed on the management of penetrating neck injuries. The Difficult Airway Society of the United Kingdom had produced guidelines for the management of the 'unanticipated' difficult airway (29), however there was little guidance available on the management of the 'anticipated' difficult airway.

2.4.3 What the paper contributed to the 'global' clinical community

The incidence of traumatic injury to the airway was confirmed to be extremely low. This was determined by the limited recent deployed experience found by interrogation of the Joint Theatre Trauma Registry and reported experience of current UK-DMS Anaesthetists. The three areas of investigation did reveal the five themes listed below.

- Penetrating injury though the mouth
- Injuries to the Face
- Laceration to the neck
- Penetrating Neck Injuries
- Carotid Artery Injury

Despite determining the five common themes above, we were unable to summarise these into the meaningful guidelines that we had hoped and had previously been achieved for the 'unanticipated' difficult airway (29) and this is a limitation to our work. What this paper was able to do however, was to summarise a series of different case reports and report on the different management techniques that had been employed by anaesthetists. This has led to the development and improvement of guidelines and allowed us to incorporate an airway workshop into the MOST Course (94). This in itself has enabled those deploying to a war zone with the potential for airway trauma to be better prepared should such cases present.

2.4.4 Where are we now?

Since publishing this article I have subsequently undertaken a systematic review on the management of non-iatrogenic airway injury (95). This manuscript is included and discussed

later in this thesis and allowed the development of specific flow diagrams and the construction of individual mental models. We have also published a discussion paper on the human factors required to manage the anticipated difficult airway (96) and this manuscript is also discussed at a later stage of this thesis. This article was initially produced to support anaesthetists in the Defence Medical Services who were deploying to Iraq and Afghanistan and this is why it was published in the *Journal of the Royal Army Medical Corps*. Recently, and much regrettably there has now been a rise in terrorist attacks on the UK-Mainland with a suicide bomber attack in Manchester at a busy concert venue recently producing complex trauma injuries that were previously only experienced in times of war (97). These guidelines and other work I will describe in this thesis is now very relevant to consultant anaesthetists involved in the treatment of victims from terrorist attacks in civilian major trauma centres.

2.4.5 Reflections on methodology

2.4.5.1 Literature Review

A literature review of all papers published after 1995 was performed and the results summarised with relevance to the anaesthetic management of penetrating head and neck injuries and case reports summarised. The literature review revealed 51 papers that were considered relevant to this study; 23 were civilian case reports and three contained military case reports. This number of articles is reasonably low and was an indication of how rare this potential problem is.

2.4.5.2 Survey of Anaesthetists in the Defence Medical Services

At the time of research there were 185 anaesthetists in the UK-Defence Medical Services. These were all contacted by email and asked to describe any cases of blast or ballistic airway injury that they had treated. There were 17 case reports submitted by DMS Anaesthetists and the cause of injury in all cases was either Gunshot wound (GSW) or Improvised Explosive

Device (IED). Limitations to this survey were that not all UK-DMS anaesthetists replied and we did not ask anaesthetists to reply if they had not experienced any cases of penetrating neck injury. With this in mind there could well have been other examples that were not reported and hence not included in the paper.

2.4.5.3 Search of the UK Joint Theatre Trauma Registry (JTTR)

The UK Joint Theatre Trauma Registry (JTTR) (98) is maintained by the Academic Department of Military Emergency Medicine at the Royal Centre for Defence Medicine. Essentially this registry contains continuous data from 2003 for all casualties who trigger a trauma team activation in either the deployed field hospital or the Primary Casualty Receiving Facility (currently the Hospital Ship RFA Argus). Over 3000 records were searched on the JTTR and 19 were identified of soldiers with penetrating head and neck injury. These injuries were either caused by blast (from an improvised explosive device, mine, mortar or rocket propelled grenade) or were due to a gunshot wound. Again, the incidence of needing to manage airway trauma during a conflict was low and this suggested the development of guidelines were important to inform and allow UK-DMS anaesthetists to rehearse prior to deployment. This registry is a comprehensive record of casualties presenting to active military medical facilities. As the review was retrospective, it relied on the data entered into the system to be accurate. There is the possibility that cases inaccurately entered were not retrieved and hence not included in the review.

2.4.6 Contribution of the Paper to Clinical Practice and what It says about me as a Researcher?

This article has been cited in the medical literature 16 times and has an Altmetric Score of 5 (9 mentions on Twitter). This article was published in 2010 in the *Journal of the Royal Army Medical Corps.* Although this journal only has an Impact Factor of 0.833 it has a readership of

current Military Personnel and individuals interested in and practicing dealing with patients with complex trauma. As described above, there were already guidelines for the management of the unanticipated difficult airway published by the UK Difficult Airway Society (29) which have now subsequently been revised (93) but there was no such guidance on the management of anticipated difficult airway in complex trauma patients. At the time this guidance was deemed to be essential by the Professor of Defence Anaesthesia, Colonel Peter Mahoney CBE L/RAMC who is a coauthor on this manuscript. This particular journal was selected as it was the one being currently read at the time by members of the Defence Medical Services preparing to deploy to Afghanistan.

The contents of this publication were used to generate a series of workshops and high fidelity simulation scenarios for the Military Operational Surgical Training Course (MOST) (13) and subsequently train UK-DMS consultants who were deploying to Afghanistan as part of Operational HERRICK. Feedback from these sessions was favorable and enabled UK-DMS consultants to further develop their own mental models prior to deployment on the management of anticipated difficult airway in trauma. These guidelines also were practiced as part of the multi-disciplinary team so that the Operating Department Practitioners (ODPs) present as part of the trauma team were aware of the management of the airway in penetrating trauma.

Following publication, a letter was written by several military anaesthetists who suggested the use of a gum elastic bougie with all intubations (99). Our subsequent systematic review article that will be discussed later suggests that this would be unwise when there is penetrating trauma below the level of the vocal cords as there is a potential for a ‘blind passage’ of the bougie (or subsequent endotracheal tube) into a false passage. The consequences of this would be devastating.

I have used the basis of this publication to develop the following further publications. These have further added to the literature around the management of the airway in penetrating trauma by anaesthetists involved in the care of patients with Complex Trauma. I have highlighted that actually the appreciation of human factors is paramount in decision making and designing the systems in which we work.

Military Publications

- Mercer SJ, Heames RM. Anaesthesia and Critical Care Aspects of Role 2 Afloat. *Journal of the Royal Navy Medical Services* 2013: **99**: 141-143
- Mercer SJ, Tarmey N, Mahoney PF. Military Experience of Human Factors in Airway Complications *Anaesthesia* 2013; **68**: 1081-1082
- Mercer SJ, Jones CP, Round J, Parkhouse D. Military Anaesthesia in Contingencies: What Skill Sets Are Required and How Will We Prepare Our Trainees? *Journal of the Royal Army Medical Corps* 2017: **163**; 226-232
- Mercer SJ, Read J, Sudheer S, Risdall JE, Connor D. What do we need for airway management of Adult Casualties on The Primary Casualty Receiving Ship? A Review of airway management on Role 3 Afloat *Journal of the Royal Navy Medical Services* 2015; **101**: 155-158

Civilian Publications

- Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma. *British Journal of Anaesthesia* 2016: **117 (S1)**: i49–i59
- Mercer SJ, Tarmey N, Park C. Human Factors in Trauma *BJA Education* 2015; **15**: 231-236

The articles listed in Table 2.4 have also cited this publication (I have only listed articles in English – there are three papers published not in English)

Table 2.4. Publications citing Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries Mercer SJ, Lewis SE, Wilson SJ, Groom P, Mahoney PF. *Journal of the Royal Army Medical Corps* 2010; **156**: S357-362

Paper	Summary
Pugh HEJ, LeClerc S, Mclennan J. A review of pre-admission advanced airway management in combat casualties, Helmand Province 2013. *Journal of the Royal Army Med Corps* 2015; 161: 121-126	In this paper, the authors undertook a retrospective review of all casualties who required advanced airway management prior to arrival at the Role 3 Hospital in Afghanistan over a 30-week period from 1 February 2013 to 23 August 2013. In effect, this was a review of the management of the airway in the pre-hospital setting in trauma patients prior to being admitted to the field hospital. This review of the advanced airway management prior to Role 3 in Helmand Province

	showed a high morbidity. Recommendations were subsequently made to improve the training of personnel operating in the pre-hospital environment.
Shuker ST. Expanding Hematoma's Life-Threatening Neck and Face Emergency Management of Ballistic Injuries *J Craniofac Surg* 2016;27:1282–1285	This is a predominantly a surgical paper, however it does cite our publication and mentions the potential pitfalls of endotracheal intubation that we described and that it should be approached with caution. The paper also describes that blind nasal intubation should be avoided and that fiberoptic intubation is likely to be difficult when there is bleeding into the airway. This citation demonstrates that my work has been read and been cited in surgical journals and the knowledge that was proposed in the original research is being translated to a wider field than just anaesthesia.
Suay RN, Bariain RT, Perez SC et al. Anesthesiological and Surgical Experiences of the Spanish Role 2 Enhanced in Herat, Afghanistan. *J Arch Mil Med* 2015;3:e26799	This publication is a summary of the experience of the Spanish Role 2 team in Afghanistan at the same time as the UK Operation HERRICK. Our paper is cited as we described from our research that the most common method to secure the airway in military trauma is using a traditional laryngoscope with an endotracheal tube.
Hindle A, Cheng J, Thabane L, Wong A. Web-Based Learning for Emergency Airway Management in Anesthesia Residency Training. *Anesthesiology Research and Practice.* 2015 (http://dx.doi.org/10.1155/2015/971406)	Our paper is quoted as 'expert option' in this review of anaesthesia residency training.
Seltz Kristensen M, McGuire B. Managing and securing the bleeding upper airway: a narrative review. Canadian Journal of Anesthesia 2019 https://doi.org/10.1007/s12630-019-01479-5	This is a narrative review is to identify techniques and strategies to be employed when severe bleeding in the upper airway renders traditional airway management impossible because of impeded vision. Our article was identified in the literature review and cited to communicate that the patient may require induction of anaesthesia 'sitting up'.

2.4.7 Where this paper places me with reference to being at the forefront of my area of professional practice.

I am now a recognised expert in the management of non-iatrogenic airway trauma and have spoken on this subject as an invited podium speaker at the following national conferences. These meetings were all approved by the Royal College of Anaesthetists for Continuous Professional Development points and delivered to a national audience of interested anaesthetists.

Title: Bombs, Bullets and Bicycles. Management of Airway Trauma
Meeting: Difficult Airway Society Annual Scientific Meeting
Location: Mermaid Theatre, London
Date: 24 November 2017

Title: Lessons from the Battlefield
Meeting: Difficult Airway Society Annual Scientific Meeting
Location: East Midlands Conference Centre, Nottingham
Date: 5 November 2011

Title: Creating Airway Guidelines for Ballistic Airway Injuries
Meeting: Tri-service Anaesthetics Society Meeting
Location: Royal College of Anaesthetists, London
Date: 2 November 2010

Title: Creating Airway Guidelines for Ballistic Airway Injuries
Meeting: Learning for each other: Civilian & Military Emergency Care Conference,
Location: International Convention Centre, Birmingham
Date: September 2010

The publications that have resulted from this article have already been discussed earlier in this thesis.

The information and knowledge that resulted from this research paper was used to develop a multi-disciplinary workshop on the management of the airway in complex trauma on the Military Operational Surgical Training Course from 2011. This important pre-deployment course for all senior anaesthetists in the Defence Medical Services ran four times a year and prepared individuals to deploy to a busy war zone. The feedback received was excellent

Section 3

Systematic Review

3.1 Introduction

I have worked with a team at Liverpool University Hospitals NHS Foundation Trust in Liverpool to produce two systematic reviews. The first paper reviews the importance of human factors in the complex trauma patient and summarises the literature on human factors highlighting work in several recent national audit reports and guidelines. The second paper concentrates on a more sub-specialist area of anaesthesia management; non-iatrogenic airway trauma. A patient who has sustained injury to their airway via either penetrating or blunt trauma will require a multi-disciplinary approach to their management, and this will require the use of exemplary human factors. Knowledge that is discovered and summarised in the systematic reviews will be discussed in further detail in Section 4.

This section of the thesis will demonstrate my involvement in the process of systematic review. It is suggested that synthesizing knowledge from a heterogenous body of literature in a clear and accurate manner can be challenging (100) but that such reviews are an increasingly influential source of useful information about the effectiveness of interventions in health care and other areas of public concern (101). In order to translate research and deliver the key messages to front line workers, the systematic review is thought to be the least biased and most rational way to summarize research evidence and then publish in the medical literature (101). The two systematic reviews I have selected have been published in the *British Journal of Anaesthesia* (Impact Factor 6.499 in 2018) and *Anaesthesia* (Impact Factor 5.431 in 2018).

A systematic review is a method used to combine evidence of multiple studies and does this by identifying relevant research, then appraising the study quality, and finally by summarising findings. Light & Pillimer commented that without a clear picture of where things stand now, simply adding one new study to the 'existing morass' was unlikely to be very useful (102). The basic steps of a systematic review include formulating a research question; finding relevant studies via a literature search; selecting and assessing the studies; summarizing and

synthesizing study results; interpreting the review results; and then maintaining and updating the review (101). Common to all knowledge synthesis methods are an explicit aim, the development of a methodological protocol, a comprehensive search strategy to find relevant research articles, a method or tradition of evaluating quality and potential risk of bias in individual studies and an explicit data collection and synthesis procedure (100).

A good systematic review can generally give us the most reliable estimate of the effectiveness of a specific intervention, and it can identify gaps in our knowledge that require further research (101). The two systematic reviews that are described in this section summarise research in the field of human factors in anaesthesia and also the anaesthetic management of non-iatrogenic airway trauma. These systematic reviews have been published in the anaesthetic literature and presented at national conferences (the process) to deliver the message to the anaesthetic community (the stakeholders).

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

Human Factors in Preventing Complications in Anaesthesia Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. *Anaesthesia* 2018; **73(S1)**: 12-24

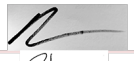
3. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (50%), original idea, organized literature review and paper selection, reviewed papers, 1st draft of manuscript and subsequent drafts. C Jones (20%) reviewed papers and subsequent drafts of manuscript. J Fawkner-Corbett (10%) reviewed papers. P Groom (15%) reviewed papers and subsequent drafts. B Morton (5%) reviewed subsequent drafts of manuscript. C Lister (10%) reviewed papers as part of the literature review.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
CPL Jones		clintonpljones@hotmail.com
J Fawkner-Corbett		jfawkner-corbett@doctors.org.uk
P Groom		petergroomx@yahoo.com
B Morton		benjmorton@doctors.org.uk
C Lister		crlister@doctors.org.uk

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	
	(Director of Studies/Advisor)		

6. Signature of Faculty Research Degrees Administrator

Signature:		Date:	
	(Faculty Research Degrees Administrator)		

Anaesthesia 2018, 73 (Suppl. 1), 12–24 doi:10.1111/anae.14136

Review Article

Human factors in preventing complications in anaesthesia: a systematic review

C. P. L. Jones,[1,4] J. Fawker-Corbett,[2] P. Groom,[1] B. Morton,[1,3] C. Lister[2] and S. J. Mercer[1,4,5]

1 Consultant Anaesthetist, 2 Specialty Trainee, Aintree University Hospital NHS Foundation Trust, Longmoor Lane, Aintree, Liverpool, UK
3 Honorary Research Fellow, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool, UK
4 Consultant Anaesthetist and Defence Lecturer, Defence Medical Services, Royal Centre for Defence Medicine, Queen Elizabeth Hospital Birmingham, Mindelsohn Way, Edgbaston, Birmingham, UK
5 Honorary Senior Lecturer, Postgraduate School of Medicine, University of Liverpool, Cedar House, Ashton Street, Liverpool, UK

Summary

Human factors in anaesthesia were first highlighted by the publication of the Anaesthetists Non-Technical Skills Framework, and since then an awareness of their importance has gradually resulted in changes in routine clinical practice. This review examines recent literature around human factors in anaesthesia, and highlights recent national reports and guidelines with a focus on team working, communication, situation awareness and human error. We highlight the importance of human factors in modern anaesthetic practice, using the example of complex trauma.

Correspondence to: S. J Mercer
Email: simonjmercer@hotmail.com
Accepted: 1 September 2017
Keywords: communication; human error; human factors; non-technical skills; patient safety; team working

Introduction

There is widespread recognition that human factors are key to the safe delivery of healthcare in the UK. Human factors are defined as: "*enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture and organisation on human behaviour and abilities and application of that knowledge in clinical settings*" [1]; or more simply, "*the science of improving human performance and well-being, by examining all the effectors of human performance*" [2].

There has been research into how human factors for anaesthetists [3], surgeons [4] and scrub practitioners [5] are translated into clinical practice. Safe and efficient task performance requires both technical and non-technical skills [6]. Deficiencies in non-technical skills at the individual level increase the chance of errors and adverse events [7]. There is also evidence that teamwork glitches, communication failures, and cultural and hierarchal barriers contribute to safety failures [8–10]. Sir Liam Donaldson, a previous Chief Medical Officer, stated that "*to err is human, to cover up is unforgivable, and to fail to learn is inexcusable*" [11]. It is hoped that the recent concordat signed by 16 organisations including the General Medical Council, NHS England and the

Care Quality Commission will lead to further embedding of human factors into everyday practice [12].

This review article examines the literature around human factors in anaesthesia, and highlights recent national reports and guidelines, with a particular focus on how their adoption can promote safer delivery of care.

Methods

We searched Medline and CINAHL for papers reporting on human factors and non-technical skills in anaesthesia. We limited the search to articles published from the year 2000 onwards, to represent contemporary practice. The search included full-text reports of articles from peer-reviewed journals published in English with no restriction to study methodology. In addition, we manually searched anaesthesia-specific journals by typing 'human factors' into the search box for *Anaesthesia, Anesthesiology, Anesthesia and Analgesia, The British Journal of Anaesthesia,* the *Canadian Journal of Anesthesia* and *European Journal of Anesthesiology,* accepting articles (not abstracts presented at conferences) from after 2000. In addition, reference lists of the manuscripts reviewed were scrutinised for additional relevant articles and book chapters.

The titles and abstracts of the references obtained were reviewed by two independent reviewers (SM and CJ). Inclusion criteria were: papers referring to human factors; non-technical skills; team resource or crew resource management; and papers published on or after 2000. Exclusion criteria were: animal studies; and papers not referring to human factors, non-technical skills team resource management or crew resource management in theatres, anaesthesia, trauma or critical care. Articles were removed if both reviewers agreed independently to exclude. In the event of agreement to include, or a discordant opinion, articles were reviewed in full by one out of five independent reviewers (SM, CJ, JC, CL and PG). Our full protocol and search strategy are registered with and published by PROSPERO (http://www.crd.york.ac.uk/PROSPERO).

The results of the literature search are described in Fig. 1.

Anaesthetists Non-Technical Skills

Work performed by the University of Aberdeen on Anaesthetists Non-Technical Skills (ANTS) [3]

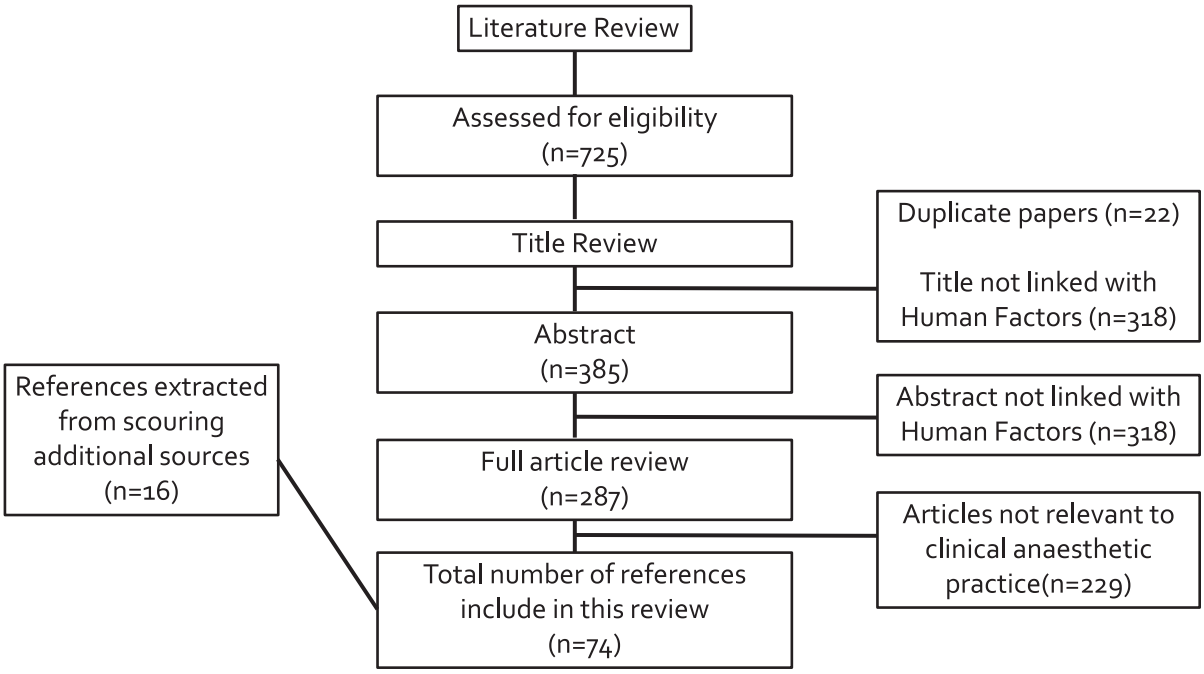


Figure 1 Systematic review literature search flow.

Table 1 The Anaesthetists Non-Technical Skills Framework [3].

Categories	Elements
Task management	• Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilising resources
Team working	• Coordinating activities with team members • Exchanging information • Using authority and assertiveness • Assessing capabilities • Supporting others
Situation awareness	• Gathering Information • Recognising and understanding • Anticipating
Decision making	• Identifying options • Balancing risks and selecting options • Re-evaluating

provides a practical framework for clinical practice (Table 1). Initial analysis showed that the ANTS system had a satisfactory level of validity, reliability and usability in an experimental setting [3]. The increasing importance of human factors has been recognised in the recommendations of several recent national reports and guidelines. In this review, we highlight some of the individual components of human factors described in the literature, and examine their importance in clinical practice by considering complex trauma management in the emergency department (ED) and in the operating theatre, as this is our subspeciality interest.

National reports and guidelines

We highlight two recent reports and two national guidelines that demonstrate the importance of human factors in anaesthesia. They share common themes that will be explored in more depth below.

The 4th National Audit Project (NAP4) [13] was the first prospective study of all major airway events occurring throughout the UK, and resulted in a review of any complications resulting from airway management that led to either death, brain damage, the need for an emergency surgical airway, unanticipated ICU admission or prolongation of ICU stay. After final review, 184 reports met the inclusion criteria, and subsequent in-depth analysis identified human factors as having been a relevant influence in every case. Latent

Table 2 Human factors recognised by NAP4 taken directly from the published report [15].

Individual and team non-technical skills	• Casual attitude to risk/overconfidence • Peer tolerance of poor standards • Lack of clarity in team structures • Incomplete or inadequate briefing and handovers/poor or non-existent debriefing • Poor or dysfunctional communication – especially between specialties • Failure to follow advice from a senior colleague • Inadequate checking procedures • Failure to request previous patient records • Failure to take and document a comprehensive history • Failure to undertake appropriate pre-operative investigations • Wrong interpretation of clinical findings/test results • Failure to use available equipment (e.g. capnography) • Attempts to use unfamiliar equipment in an emergency situation • Failure to cope with stressful environment/interruptive workplace • Failure to formulate back-up plans and discuss with the team members • Fixation errors, resulting in a failure to recognise and abort a plan which is not working, and move to another potential solution • Frequent/last minute changes of plan
System design and management	• Equipment shortages • Inadequate maintenance of equipment • Incompatible goals (e.g. conflict between financial and clinical need) • Reluctance to undertake a formal analysis of adverse events/learn from errors • Loss of documentation (e.g. previous patient records not available) • Inadequate systems of communication • Highly mobile working arrangements leading to difficulties in communication • Inexperienced personnel working unsupervised • No scheduled training sessions for updating staff in the use of new techniques/equipment • Incomplete training/inadequate knowledge or experience • Heavy personal work-loads/lack of time to undertake thorough assessments • Organisational and professional cultures which induce or tolerate unsafe practices • No requirement at organisational level to undertake formalised checking procedures

Table 3 Human factors recognised by NAP5.

Induction of anaesthesia	• Drugs errors (mislabelling, syringe swaps, failure to mix drugs, underdosing due to lack of knowledge) • Distraction (by colleagues or by unexpected difficulty) • Timing (rushing, busy lists with multiple changes) • Fatigue • Seniority (unsupervised juniors, lack of knowledge)
Maintenance of anaesthesia	• Underdosing (due to cardiovascular instability, risk to fetus, inattention/ judgement errors)
Emergence from anaesthesia	• Switching off anaesthetic agents too early due to poor communication or lack of knowledge • Failure to monitor neuromuscular blockade • Rushing and mistiming

threats (poor communication, poor training and teamwork, deficiencies in equipment, and inadequate systems and processes) predisposed to loss of situational awareness and subsequent poor decision making [14]. We have divided human factors errors into individual and team non-technical skills and system and design management (Table 2).

The 5th National Audit Project (NAP5) [16] on accidental awareness during general anaesthesia (AAGA) reported that two-thirds of awareness occurred during induction and emergence. Contributing factors included: the use of thiopentone; rapid sequence induction (RSI) of anaesthesia; obese patients; difficult airway management; neuromuscular blockade; and transfers to theatre [16]. Of those cases of AAGA reported, 73% were deemed to be avoidable, with miscommunication found to be the main contributory factor in greater than 80% cases of AAGA associated with sedation. Human factors recognised by NAP5 are described in Table 3.

The Difficult Airway Society (DAS) guidelines for unanticipated difficult airway 2015 [17] included a whole section on human factors, and incorporated recommendations made by the NAP4 report. The guidelines highlight the importance of clinician awareness that poor communication, poor training and teamwork, deficiencies in equipment, and inadequate systems and processes predispose to loss of situation awareness and subsequent poor decision making. In stressful situations such as cannot intubate, cannot oxygenate (CICO), anaesthetists can become overloaded, and the DAS guidelines provide explicit instructions for the team to 'stop and think'. A 'declaration of the emergency' ensures that all members of the team start this critical situation on the 'same page' and can follow the same mental model (i.e. follow the DAS Guidelines).

It is also important that teams rehearse together and consider using simulation to develop non-technical skills, such as: leadership; team co-ordination; communication; and shared understanding of roles [17]. A team brief before the start of each anaesthetic, particularly between anaesthetist and operating department practitioner (ODP) is also considered to be good practice, and encourages thinking about specific challenges and checking availability of appropriate equipment.

The DAS guidelines for the management of tracheal extubation [18] recognised that human factors compound problems related to tracheal extubation. Problems arise when there is inadequate equipment, inadequate skilled assistance, suboptimal patient positioning, limited access to airway (e.g. due to dressings/ gastric tubes/rigid fixators), interruption of oxygen supply during patient transfer, communication difficulties (e.g. language, mental capacity) and the removal of oxygen by agitated or uncooperative patient.

Human factor components

Teamwork

The term 'teamwork' describes a number of behavioural processes and emergent states [19] and is defined as "*a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal, who have each been assigned specific roles or functions to perform, and who have a limited life-span membership*" [20]. Although teams consist of individuals, it is important to work towards maximising the mental and physical problem-solving capabilities of the group, such that the sum is greater than its parts [21]. In complex teams, teamwork is more than just subordinates doing what their leader tells them to do, and relies on good followership; followership is 'the active engagement of

followers in helping the group achieve its goals' [22]. Good teamwork is associated with improved productivity, innovation and job satisfaction [23]. Teams who demonstrate similar mental models move quicker through the phases common to most crises. This is important, particularly in complex trauma [24].

Communication

It is estimated that communication failures account for 43% of errors in the operating theatre in the USA [25]. Communication failures can be categorised as follows: the provision of insufficient information; poor timing of the communication (e.g. too late); unresolved issues at the end of the communication; or the absence of key personnel [26]. In time-critical situations, it is important that there is a team leader who can impart critical information without the potential for misinterpretation or misunderstanding, irrespective of the situation or the composition of the team.

Effective communication relies on clarity ('keeping it clear'), brevity ('keeping it brief)', empathy, ('how will it feel to receive this?'), with provision for a feedback loop. Directed communication and closed-loop communication is particularly important when rapid response is critical, and involves specification of who the order or communication is directed towards, usually by using a hand signal or saying the person's name [27]. It is vital that an atmosphere of open information exchange is achieved by empowering all team members to speak out. Barriers to challenging include poor communication skills [28, 29] and poor intra-operative communication between seniors and juniors [30], and should be taught as part of the anaesthetic curriculum [31].

A shared mental model promotes an accurate understanding of the facts, defends against error and allows the cognitive resources of the entire team to be fully leveraged for decision making and error detection [32]. This model can be facilitated by a team brief, which needs to include the following: the introduction of all team members by name and role; a briefing as to what is expected to happen; and allocation of tasks. An example of this is the World Health Organization (WHO) Safety Checklist [33]. To maintain effective communication during a critical emergency, it is vital that increased noise does not cause distraction. A 'sterile cockpit' has been described in the airline industry during key moments, and is also vital in emergency patient care [34]. This is achieved by the noise level being kept to an absolute minimum, and is reliant on good 'crowd control' so that excessive noise levels are kept low.

It is important to adopt a culture of good communication. There is evidence that nurses and trainee doctors do not feel sufficiently empowered during interactions with senior doctors. Factors responsible for this include: hierarchy; sex; differing patient care responsibilities; differing perceptions of requisite communication standards; and differences in the training methods [35].

Situational awareness

Situational awareness is the continuous monitoring of the task, detection of events, and changes in the environment. Almost all aspects of anaesthetists' intra-operative tasks rely heavily on their vigilance and situational awareness skills [36]. Situational awareness can be defined by three questions: 'Where have we come from?'; 'Where are we now?'; and 'Where are we going?' [37]. Practically, factors such as clinical signs and physiology seen on the monitors, the rest of the operating theatre team and other technology are vital to inform situational awareness [38]. The importance of a shared situational awareness is key to effective teamwork, and in the military this is improved by regular updates by the team leader in the form of situational updates ('sitreps') [24]. The three levels of situational awareness and an error taxonomy are described in Table 4.

Human error

It is reported that there is an average of one error in every 133 anaesthetics, and 130 errors for every 1000 patient ICU days [39]. Anaesthetic drug errors are commonly caused by slips and lapses, fixation errors (failure to revise a situation assessment as new evidence emerges) [40], mistakes, knowledge-based errors and deliberate violations [41]. Recommendations to avoid drug errors include the following:

- Careful inspection of labels before a drug is drawn up or injected.
- Optimise label legibility and contents on syringes, according to agreed standards.

Table 4 Levels of situational awareness and error taxonomy – adapted from Endsley [37].

Level 1 situational awareness: failure to correctly perceive the situation 'Where have we come from?'	• The data are not available
	• The data are difficult to detect or perceive
	• There is a failure to scan or observe data due to
	  ○ Omission
	  ○ Attentional narrowing or distraction
	  ○ High taskload of individual
	• There is misperception of the data
	• Individual memory failure

Level 2 situational awareness: failure to comprehend situation 'Where are we now?'	• Lack of or a poor mental model • Use of the incorrect mental model • Over-reliance on default values in the mental model • Individual memory failure
Level 3 situational awareness: failure to project situation into the future 'Where are we going?'	• Lack of or a poor mental model
General	• Failure to maintain multiple goals • Habitual schema

- Formal organisation of drug drawers and workspace.
- Second checker for labels before a drug is drawn up or administered.
- Thorough reporting and review of intravenous drug administration errors.
- Manage drug inventory to focus on minimising the risk of drug error.
- Avoid similar packaging and presentation of drugs where possible.

Accidents occur due to the interrelationship between real-time 'unsafe acts' by front-line operators and latent conditions [42]. In Reason's classical 'Swiss cheese' model, this is thought to be due to 'holes' appearing in the multiple levels of the system, and that when these holes line up, as in multiple slices of Swiss cheese, an accident can occur. 'The Parmesan cheese model' [43] may be a better representation of the clinician's responsibility in routine patient care, and the importance of minimising any deficiencies in routine practice. In this analogy, small shavings from the cheese occur every time our practice contributes to substandard practice; 'with each shave – no matter how small – we remove from the whole', thereby decreasing the chances of optimal patient outcome [43].

Observable team errors may be classified into five basic types.

1 Task execution – an unintentional physical act that deviates from the intended course of action.
2 Procedural – an unintentional failure to follow mandated procedures.
3 Communication – a failure to transmit information, failure to understand information or failure to share a mental model.
4 Decision – a choice of action unbounded by procedures that unnecessarily increase hazard and
5 Intentional non-compliance – violations of formal procedures or regulations [44]. Latent errors in the operating theatre are further classified as follows [45]:

- Equipment, design and maintenance (availability, functioning, standardisation of design and maintenance of machines).
- Staffing (adequate staffing and skills).
- Communication (work-directed communication, openness, interrelation and atmosphere).
- Training (training for machines, procedures and team training).
- Teamwork and team training (team performance).
- Procedures (presence of protocols and adherence to protocols).
- Situational awareness (awareness of present situation, own tasks and future developments).
- Incompatible goals (balance between goals and safety).

Table 5 Emergency department contributory factors to poor critical decision making, delayed diagnosis and missed injury. To be considered before delivery of high risk anaesthetic interventions.

Patient factors	Evolving pathophysiology (medical and surgical) Altered level of consciousness – inability to take a history Haemodynamic and respiratory compromise Minimal clinical assessment completed so far Distracting injuries Multiple injuries Child vs. adult Urgency of clinical problem
Provider factors	Lack of knowledge, inexperience Failure to adapt (low to high mental work-load) Lack of skilled assistance Complacency Fatigue Emotive case Practical difficulties and frustration Failure to re-assess Confirmation bias Poor team dynamics Ineffective communication • Hierarchical gradients [46] • Loss of situational awareness • Poor followership
Environmental factors	Unfamiliar clinical environment Increased auditory and physical distractions • Raised noise levels – crowd control • Multiple equipment alarms [47] • Increased staff observation & movement Ergonomic design – visibility of patient monitor Equipment familiarity and maintenance Remote from specialist anaesthetic equipment Remote from immediate senior anaesthetic support Delayed access to specialist surgical support and imaging Standardised operational procedures and cognitive aids

- Planning and organisation (process of care).
- Housekeeping (hygiene).

The importance of human factors in clinical practice

The authors work in a busy major trauma centre in the North-West of England. We have taken the results of the literature review and applied this to our clinical practice. Much of these findings are generalisable into other areas of clinical anaesthesia.

Emergency department

Anaesthetists are frequently called to support critically unwell, time-critical patients in the ED. At the time of the call, patients may physically be in the department or en route. This can result in overwhelming or inadequate clinical information, respectively. Both circumstances provide an immediate cognitive load and increased risk of cognitive errors. These patients frequently require high-risk anaesthetic interventions to promote safety, but there is minimal time to consider factors that may prevent poor critical decision-making (Table 5).

There are increased distractions, mental workload and cognitive pressures in ED that further increase the risk of team errors. These include in particular deviation from standardised operating procedures, not using cognitive aids (checklists), violations of formal procedures or regulations and intentional non-compliance [44]. Lack of familiarity and poor ergonomic design of ED resuscitation bays can have a significant negative impact on situational awareness. Fatigue, frequently encountered on call, can further exacerbate this situation. Fatigue has been reported to degrade or cause variability in performance by reducing attention–vigilance, slowing cognitive throughput, impairing memory and decision making, prolonging reaction time and disrupting communications. When managing high-acuity patients in ED, it takes only a moment of reduced performance during a critical task to have a negative outcome [48].

The reception and resuscitation of a critically unwell patient in ED can be divided a number of stages.

Initial handover

Pre-hospital teams should give a pre-alert notification for admission of all critically unwell patients to the ED. This allows time to assemble appropriately-skilled resources and can trigger several defined protocols for preparation of key interventions and additional logistical, specialist support (e.g. activation of trauma vs medical cardiac arrest teams, major haemorrhage protocol, paediatric and obstetric teams, and ensuring an emergency theatre is on stand-by to receive). On

Table 6 Elements of the AT-MIST pre-alert and handover.

Trauma	Medical
Age (include name for handover)	**A**ge (include name for handover)
Time of incident	**T**ime of onset
Mechanism of injury	**M**edical complaint/history
Injuries top to toe	**I**nvestigations (brief examination findings)
Vital **s**igns (first set and significant changes)	Vital **s**igns (first set and significant changes)
Treatment	Treatment
Additional pre-alert information: Estimated time of arrival Mode of transport Specialist resources standing by	Additional pre-alert information: Estimated time of arrival Mode of transport Specialist resources standing by

arrival, the handover must be delivered in a standardised manner. Although there is variability among services, many use the AT-MIST acronym (Table 6). Early and robust decisions are required from the team leader, often in conjunction with the anaesthetic team and other specialties present. A formalised handover process ensures that the team is prepared and 'switched on' to receive crucial information in complete silence, and ready to assimilate this information into orders of priority. However, this process may fall short when handovers are inadequate and the mental model is no longer 'shared'; this is referred to this as 'the Bermuda Triangle of healthcare' [49].

Primary systematic assessment

The role of the designated team leader is to allocate roles (according to clinical competencies) and facilitate a primary systematic assessment and other subsequent tasks in a 'horizontal fashion' [50]. Systematic re-assessments are vital for the management of complex critically unwell patients. This process permits shared understanding (especially important in evolving pathophysiology), the formulation of clear mental models and supports subsequent critical decisions. Failure to perform re-assessment promotes cognitive bias and may impact on critical decision, for example, computed tomographic (CT) imaging vs. immediate surgical intervention, or critical care support vs. recognition of futility and palliation.

Communication for critical decisions

Best practice management of critically unwell patients in the ED requires a multidisciplinary team approach with excellent communication. The key to delivering damage control resuscitation and surgery has been shown to be effective communication [51]. Although this requirement is self-evident, the principles to achieving this can be forgotten or be suboptimal in stressful situations. In response to this, the Trauma WHO checklist has been proposed to improve and streamline communication during the damage control resuscitation [24]. This checklist has been tested and modified in a military field hospital in Afghanistan [52], and the main elements are described in Table 7. The key features of the Command Huddle (described below) could be applied within NHS practice to all ED medical and surgical resuscitations. Following initial assessment and resuscitation the team leader should have formulated their own mental model and plan. Before presenting it to the team, the team leader should share and exchange critical information with key members (anaesthetist, surgeon, medical physician, intensivist, theatre lead etc.). Once agreed on a shared mental model, the team leader presents their plan and explores opinions from key members. The objective of the command huddle is to formulate a plan of action with clear order of priorities.

Emergency department rapid sequence induction

During the command huddle, the anaesthetist needs to justify why an ED RSI of anaesthesia is required, and complete their own risk vs. benefit analysis (Table 8). The less situationally aware anaesthetist may immediately agree to delivering an RSI, especially for a patient with a 'solid' indication(s). This is fraught with danger unless there is clear understanding of the patient's pathology, consideration of specific anaesthetic cautions and contingency planning to manage unanticipated difficulty with tracheal intubation. As outlined in NAP4, the incidence of serious airway complications causing death or brain damage is significantly greater in the ED, with at least one in 50,000 anaesthetics requiring a surgical airway [13]. The 2015 Difficult Airway Society guidelines suggest waking a patient up when both tracheal intubation and supraglottic airway

Table 7 The Trauma World Health Organisation checklist.

Command Huddle	Following the primary and secondary survey the team leader uses the information gleaned from the handover from the pre-hospital team, the physical examination, imaging and blood test to arrive at a decision on the next step in patient care. This is often transfer to the CT scanner, but may involve direct transfer to the operating theatre or critical care.
Snap Brief	Before commencing surgery there is a reconfirmation of vital information to ensure the right patient is in theatre followed by a recap of the mechanism of injury, the injuries sustained, any additional radiology results and then the surgical and anaesthetic plans.
Sit-Reps	Every 10–30 min there will be an update or 'sit-rep', usually when additional information is known. The acronym STACK acronym can be used to facilitate this. • S = Systolic BP • T = Temperature • A = Acidosis • C = Coagulation • K = Kit (Including blood products used)
Debrief	At a convenient moment when the case has finished there will be a debrief for all team members.

device insertion have failed [17], however, this may not be possible for patients receiving an RSI for indications 1–3 (see below), and requires careful discussion and planning.

Improving safety requires engagement. Emerging evidence regarding safer practices offer substantial gains in safety, but only if effectively implemented [44]. Developing methods for a systematic approach to the safety of ED RSI is supported by results in other high-reliability organisations [45]. Without this, the effectiveness of human factor training and awareness would necessarily be limited. Safety culture, specifically for the use of ED RSI checklists, has increased since the implementation of the WHO surgical safety checklist [53] and following recommendations from NAP4 [13] to use cognitive aids for emergency anaesthesia. A systematic approach to safety around RSI in the ED is described in Table 9.

It is not uncommon to perform complex procedures in ED (e.g. emergency resuscitative thoracotomy), or to undertake prolonged resuscitation before critical care admission or performing a tertiary transfer to a specialist hospital. When this occurs, there is often a transfer of leadership to the anaesthetist.

The operating theatre

The operating theatre is recognised as a high-risk, accident-prone environment where the consequences of failure can be catastrophic [53], and failures in non-technical skills, particularly communication [25] and teamwork have contributed to adverse events [54]. To elucidate these, we have focused on four specific areas: handover; hierarchy; checklists; and equipment. Again, we have used complex trauma as an example, as this is often a complex situation that is highly stressful, involving a multidisciplinary team and where individuals are frequently placed out of their own comfort zones.

Handover

The use of checklists and protocols has been shown to improve the routine handover of patients [55]. In an evolution of these, electronic handovers have been tested and also found to be useful [56]. Failed communication upon transfer of care may lead to adverse events [56]. In the example of complex trauma, there should be a formal handover from the trauma team leader to the lead anaesthetist in the operating theatre. This process ensures that the whole trauma team are aware of who the team leader is at all times [57].

Hierarchy

In emergency situations, it is important that members of the team are empowered to challenge their seniors. 'Speaking-up', or the ability to effectively challenge erroneous decisions, is essential to preventing harm; despite significant multifactorial barriers, systematic training in effective 'speaking up' could improve the confidence and ability of juniors to challenge erroneous decisions [31]. Perceived barriers to challenging include the following: assumed hierarchy; fear of embarrassment of self or others; concern over being misjudged; fear of being wrong; fear of retribution; jeopardising an ongoing relationship; natural avoidance of conflict; and concern for reputation [58]. In the

Table 8 Indications for emergency department anaesthesia – a risk vs. benefit analysis of 'hard' (1–3) and 'soft (4–6) indications.

Indication	Consider?	Actions, specialist equipment and additional personnel
1 Actual or impending airway compromise	Ensure mechanism fully understood (blunt, penetrating, burn injuries, anaphylaxis, foreign body, malignancy, infectious etc.)	Videolaryngoscopy Fibreoptic bronchoscope Difficult airway trolley ENT surgeon present
2 Ventilatory failure	Risk stratify patients at high risk of apnoeic desaturation [74].	Optimise patient position, consider adding PEEP, provide apnoeic oxygenation ± positive pressure ventilation pre-intubation.
3 Unconsciousness	Could this be secondary to an unsecured intracranial aneurysm?	Caution with RSI drugs used – avoid hypertensive response to laryngoscopy.
4 Unmanageable and agitated after head injury	Consider 'delayed sequence induction' to improve oxygenation and i.v. access before completing RSI [75].	Use small boluses of ketamine to achieve sedation, preserve airway reflexes and maintain spontaneous breathing.
5 Anticipated clinical course	This rarely applies in a hospital setting. Analyse clinical progression and risk of performing RSI later in theatre.	Continue to improve physiology and re-assess.
6 Humanitarian need	Dependent on patient cooperation.	Consider multi-modal analgesia and sedation for anxiolysis vs. delayed sequence induction to get control.

PEEP, positive end-exporatory pressure; RSI, rapid sequence induction; ENT, ear, nose and throat; i.v., intravenous.
'Code Red' patients: ensure there is large bore i.v. access, that the major haemorrhage protocol activated and consider starting blood pre-RSI using a rapid transfuser.
Blunt trauma: at the level of the larynx or below can be difficult to diagnose. The hallmark of airway management for such patients is the maintenance of spontaneous ventilation, intubation under direct vision to avoid the creation of a false passage, and avoidance of both intermittent positive pressure ventilation and cricoid pressure (the latter for laryngotracheal trauma only) during a rapid sequence induction of anaesthesia [76].
Severe metabolic acidosis: often seen in patients with septic shock or metabolic crises (e.g. diabetic ketoacidosis). Consider ventilating these patients through the apnoeic phase, as a mixed respiratory and metabolic acidosis during this time can cause the pH to fall sharply and precipitate cardiac arrest.

Table 9 A systematic approach to the safety of emergency department rapid sequence induction (RSI).

- 'Stop and Think'
- Consider indication for emergency anaesthesia (risk stratification for apnoeic hypoxia)
- Consider RSI drug regime as per a standardised approach
- Use of Emergency Department RSI checklist
- Strict clinical governance

airline industry, the acronym 'CUS'-'I'm concerned,' 'I'm uncomfortable,' and 'this is unsafe or I'm scared' is used to challenge in a crisis situation [59].

Further steps that we think are important in further flattening the medical hierarchy include [60]:

- Encouraging staff to address each another by their first name.
- Trying to create an inclusive atmosphere.
- Consultants specifically inviting juniors to ask questions and vocalise uncertainties
- Agreeing at departmental and national professional level to a 'two-challenge rule' triggering the involvement of a second consultant, without threat of professional sanction.
- Regular consultant assessment by juniors.

Checklists

The primary purpose of checklists is to avoid unintentional harm by accounting for mental fallibility [61]. There are cultural hurdles to implementing checklists [62], and acceptance of these cognitive aids requires a certain amount of humility in a profession known for independence and authority [61]. 'Smart Checklists'

are designed not to threaten provider autonomy, but to mentally offload the many repetitive tasks in healthcare that must be completed in a largely predictable sequence [63]. Displaying cognitive aids during emergencies reduces omissions, time to perform tasks and improves team skills, communication and performance in most instances [64].

As described above, the WHO surgical safety checklist [53] was introduced in 2009 with the primary aim of eliminating 'never events', and has recently been reported to reduce hospital mortality [65]. This process involves a team brief and then a series of questions to review key aspects of the operation, any patient-specific factors and any unusual steps in the process.

It has been suggested that during an emergency there is potential unwillingness or inability to revert to more systematic thinking [66]. During stress, there is an increase in cortisol and other stress hormones, which can lead to cognitive and behavioural changes. This may account for deficiencies in recalling information, missed treatment steps or mistakes in sequential procedures [67]. The use of cognitive aids during simulation scenarios has demonstrated improvements in the management of anaesthetic emergencies such as malignant hyperpyrexia [68] and local anaesthetic toxicity [69]. Individual anaesthetists' decisions to follow or deviate from guidelines are influenced by the beliefs held about the consequence of their actions, the direct or indirect influence of others, and the presence of factors that encourage or facilitate particular courses of action [70].

Accepting a cognitive aid like a checklist requires a certain amount of humility. Use of such aids is now seen as a sign of strength, whereas failing to use them may be regarded as a weakness, and of perhaps taking on unwarranted risk. To avoid complacency, completion of an RSI checklist is a two-person task, following a 'challenge' and 'response' process. Visual and tactile checks are completed before the responder confirming a positive or negative response. A 'pre-induction of anaesthesia checklist' has been shown to significantly improve information exchange, knowledge of critical information and perception of safety in anaesthetic teams [71].

Equipment

The design of equipment is crucial in the field of human factors. One very topical equipment issue currently is the universal Luer connector and its role in intrathecal administration of drugs. In the UK, in 2001, Wayne Jowett, a teenager who was in remission from leukaemia, died following the intrathecal administration of vincristine [72]. The Luer lock connection had enabled the vincristine syringe to be attached to the spinal needle, thereby removing the final safeguard for the patient [72]. Similar tragedies have been reported with chlorhexidine cleaning solution administered epidurally [73]. Although this problem was recognised over 40 years ago, there is still no satisfactory solution. NHS trusts and independent healthcare institutions in England and Wales were supposed to have taken action to use spinal needles with non-Luer connectors by 1 April 2011, but unfortunately this still has not been achieved. Although there are other examples of unresolved equipment safety issues, this is perhaps the most serious unresolved equipment risks that anaesthetists regularly encounter.

Conclusion

Recognition of human factors is now firmly embedded into clinical anaesthetic practice, and has been highlighted in several recent national reports and guidelines. We have reviewed the current literature and described the human factor components of teamwork, communication and situation awareness; we have also commented on human error. The importance of human factors in clinical practice has been highlighted using the example of complex trauma in the ED and the operating theatre.

Acknowledgements

No external funding or competing interests declared.

References

1. Catchpole K. Cited in department of health human factors reference group interim report, 1 March 2012, National Quality Board. March 2012. http://www.england.nhs.uk/ourwork/part-rel/nqb/ag-min/ (accessed 26/05/2017).
2. Moneypenny MJ. When are 'human factors' not 'human factors' in can't intubate can't oxygenate scenarios? When they are 'human' factors. *British Journal of Anaesthesia* 2017; **118**: 469–9.
3. Fletcher G, Flin R, McGeorge P, et al. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *British Journal of Anaesthesia* 2003; **90**: 580–8.
4. Yule S, Flin R, Paterson-Brown S, et al. Development of a rating system for surgeons' non-technical skills. *Medical Education* 2006; **40**: 1098–104.

5. Mitchell L, Flin R. Non-technical skills of the operating theatre scrub nurse: literature review. *Journal of Advanced Nursing* 2008; **63**: 15–24.
6. Flin R, O'Connor P, Crichton M. *Safety at the sharp end: a guide to non-technical skills*. Farnham, UK: Ashgate, 2008.
7. Flin R, Patey R, Glavin R, et al. Anaesthetists' non-technical skills. *British Journal of Anaesthesia* 2010; **105**: 38–44.
8. Greenberg CC, Regenbogen SE, Studdert DM, et al. Patterns of communication breakdowns resulting in injury to surgical patients. *Journal of the American College of Surgeons* 2007; **204**: 533–40.
9. Rosenstein AH, O'Daniel M. Impact and implications of disruptive behavior in the perioperative arena. *Journal of the American College of Surgeons* 2006; **203**: 96–105.
10. Lingard L, Reznick R, Espin S, et al. Team communications in the operating room: talk patterns, sites of tension, and implications for novices. *Academic Medicine* 2002; **77**: 232–7.
11. Feinmann J. Why sorry doesn't need to be the hardest word. *British Medical Journal* 2011; **342**: d3258.
12. NHS England. Human factors in healthcare – a concordat from the National Quality Board. http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf(accessed 26/05/2017).
13. Cook TM, Woodall N, Frerk C, et al. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. *British Journal of Anaesthesia* 2011; **106**: 617–31.
14. Flin R, Fioratou E, Frerk C, et al. Human factors in the development of complications of airway management: preliminary evaluation of an interview tool. *Anaesthesia* 2013; **68**: 817–25.
15. Cook T, Woodall N. NAP 4. Major complications of airway management in the United Kingdom. Report and Findings March 2011 Section 2. Clinical Reviews. http://www.rcoa.ac.uk/node/1413 (accessed 27/05/2017).
16. Cook TM, Andrade J, Bogod DG, et al. 5th National Audit Project (NAP5) on accidental awareness during general anaesthesia: patient experiences, human factors, sedation, consent, and medicolegal issues. *British Journal of Anaesthesia* 2014; **113**: 560–74.
17. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *British Journal of Anaesthesia* 2015; **115**: 827–48.
18. Mitchell V, Dravid R, Patel A, et al. Difficult Airway Society Guidelines for the management of tracheal extubation. *Anaesthesia* 2012; **67**: 318–40.
19. Valentine MA, Nembhard IM, Edmondson AC. Measuring teamwork in health care settings: a review of survey instruments. *Medical Care* 2015; **53**: e16–30.
20. Salas E, Burke CS, Stagl KC. Developing teams and team leaders: strategies and principles. In: David VD, Stephen JZ, Stanley M, eds. *Leader development for transforming organizations: growing leaders for tomorrow*. Hove, UK: Psychological Press, 2004: 325–55.
21. Pierre MS, Hofinger G, Buerschaper C, Simon R. *Crisis management in acute care settings*. Berlin, Germany: Springer, 2011.
22. Hogg MA. Social identity processes and the empowerment of followers. In: Riggio RE, Chaleff I, Lipman-Blumen J, eds. *The art of followership how great followers create great leaders and organisations*. San Francisco, CA: Wiley, 2008: 267.
23. Katzenbach JR, Smith DK. *The wisdom of teams: creating the high-performance organization*. New York: Harper Business, 1993.
24. Arul GS, Pugh H, Mercer SJ, et al. Optimising communication in the damage control resuscitation-damage control surgery sequence in major trauma management. *Journal of the Royal Army Medical Corps* 2012; **158**: 82–4.
25. Gawande A, Zinner MJ, Studdert DM, et al. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003; **133**: 614–21.
26. Lingard L. Communication failures in the operating room: an observational classification of recurrent types and effects. *Quality and Safety in Health Care* 2004; **13**: 330–4.
27. Guise J-M, Segel S. Teamwork in obstetric critical care. *Best Practice & Research Clinical Obstetrics and Gynaecology* 2008; **22**: 937–51.
28. Okuyama A, Wagner C, Bijnen B. Speaking up for patient safety by hospital-based health care professionals: a literature review. *BMC Health Services Research. BioMed Central* 2014; **14**: 61.
29. Kobayashi H, Pian-Smith M, Sato M, et al. A cross-cultural survey of residents' perceived barriers in questioning/challenging authority. *BMJ Quality and Safety* 2006; **15**: 277–83.
30. Belyansky I, Martin TR, Prabhu AS, et al. Poor resident-attending intraoperative communication may compromise patient safety. *Journal of Surgical Research* 2011; **171**: 386–94.
31. Beament T, Mercer SJ. Speak up! Barriers to challenging erroneous decisions of seniors in anaesthesia. *Anaesthesia* 2016; **71**: 1332–40.
32. Weller JM, Merry AFI. Best practice and patient safety in anaesthesia. *British Journal of Anaesthesia* 2013; **110**: 671–3.
33. World Health Organisation. Surgical Safety Checklist. 2008. http://www.who.int/patientsafety/safesurgery/checklist/en/ (accessed 27/05/2017).
34. Broom MA, Capek AL, Carachi P, et al. Critical phase distractions in anaesthesia and the sterile cockpit concept. *Anaesthesia* 2011; **66**: 175–9.
35. Reader TW, Flin R, Mearns K, et al. Interdisciplinary communication in the intensive care unit. *British Journal of Anaesthesia* 2007; **98**: 347–52.
36. Flin R, Maran R. Basic concepts for crew resource management and non-technical skills. *Best Practice & Research Clinical Anaesthesiology* 2015; **29**: 27–39.
37. Endsley MR. Measurement of situation awareness in dynamic systems. *Human Factors* 1995; **37**: 65–84.
38. Fioratou E, Flin R, Glavin R, et al. Beyond monitoring: distributed situation awareness in anaesthesia. *British Journal of Anaesthesia* 2010; **105**: 83–90.
39. Mahajan RP. Medication errors: can we prevent them? *British Journal of Anaesthesia* 2011; **107**: 3–5.
40. De Keyser V, Woods DD. *Fixation errors: failures to revise situation assessment in dynamic and risky systems*. Netherlands: Springer, 1990.
41. Glavin RJ. Drug errors: consequences, mechanisms, and avoidance. *British Journal of Anaesthesia* 2010; **105**: 76–82.
42. Reason J. Human error: models and management. *British Medical Journal* 2000; **320**: 768–70.
43. Moloney J. Error modelling in anaesthesia: slices of Swiss cheese or shavings of Parmesan. *British Journal of Anaesthesia* 2014; **113**: 905–6.
44. Helmreich RL, Davies JM. Culture, threat, and error: lessons from aviation. *Canadian Journal of Anesthesia* 2004; **51**: R1–4.
45. van Beuzekom M, Boer F, Akerboom S, et al. Patient safety: latent risk factors. *British Journal of Anaesthesia* 2010; **105**: 52–9.

46. Bould MD, Sutherland S, Sydor DT, et al. Residents' reluctance to challenge negative hierarchy in the operating room: a qualitative study. *Canadian Journal of Anesthesia* 2015; **62**: 576–86.
47. Edworthy J, Hellier E. Alarms and human behaviour: implications for medical alarms. *British Journal of Anaesthesia* 2006; **97**: 12–17.
48. Gaba DM, Howard SK. Fatigue among clinicians and the safety of patients. *New England Journal of Medicine* 2002; **347**: 1249–55.
49. Landro L. The informed patient: hospitals combat errors at the ''hand-off;'' new procedures aim to reduce miscues as nurses and doctors transfer patients to next shift. *Wall Street Journal* 2006. https://www.wsj.com/articles/SB115145533775992541 (accessed 27/05/2017).
50. Smith J, Russell R, Horne S. Critical decision-making and timelines in the emergency department. *Journal of the Royal Army Medical Corps* 2011; **157**: 273.
51. Mercer SJ, Arul GS, Pugh HEJ, et al. Performance improvement through best practice team management – human factors in complex trauma. *Journal of the Royal Army Medical Corps* 2014; **160**: 105–8.
52. Arul GS, Pugh H, Mercer SJ, et al. Human factors in decision making in major trauma in Camp Bastion, Afghanistan. *Annals of Surgery* 2015; **97**: 262–8.
53. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *New England Journal of Medicine* 2009; **360**: 491–9.
54. Catchpole K, Mishra A, Handa A, et al. Teamwork and error in the operating room. *Annals of Surgery* 2008; **247**: 699–706.
55. Segall N, Bonifacio AS, Schroeder RA, et al. Can we make postoperative patient handovers safer? a systematic review of the literature. *Anesthesia & Analgesia* 2012; **115**: 102–15.
56. Weinger MB, Slagle JM, Kuntz AH, et al. A multimodal intervention improves postanesthesia care unit handovers. *Anesthesia & Analgesia* 2015; **121**: 957–71.
57. Mercer SJ, Tarmey NT, Woolley T, et al. Haemorrhage and coagulopathy in the Defence Medical Services. *Anaesthesia* 2012; **68**: 49–60.
58. Pian-Smith MCM, Simon R, Minehart RD, et al. Teaching residents the two challenge rule: a simulation based approach to improve education and patient safety. *Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare* 2009; **4**: 84–91.
59. Leonard M. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Quality and Safety in Health Care* 2004; **13**(S1): i85–90.
60. McMaster E, Phillips C, Broughton N. Righting the wrongs of traditional medical hierarchy. *Anaesthesia* 2015; **71**: 110–1.
61. Grigg E. Smarter clinical checklists. *Anesthesia & Analgesia* 2015; **121**: 570–3.
62. Gawande A. *The checklist manifesto: how to get things right*. London: Profile, 2009.
63. Hales BM, Pronovost PJ. The checklist – a tool for error management and performance improvement. *Journal of Critical Care* 2006; **21**: 231–5.
64. Marshall SD. Helping experts and expert teams perform under duress: an agenda for cognitive aid research. *Anaesthesia* 2016; **72**: 289–95.
65. van Klei WA, Hoff RG, van Aarnhem E, et al. Effects of the introduction of the WHO 'Surgical Safety Checklist' on in-hospital mortality: a cohort study. *Annals of Surgery* 2012; **255**: 44–9.
66. Jenkins B. Cognitive aids: time for a change? *Anaesthesia* 2014; **69**: 660–4.
67. Kuhlmann S, Piel M, Wolf OT. Impaired memory retrieval after psychosocial stress in healthy young men. *Journal of Neuroscience* 2005; **25**: 2977–82.
68. Harrison TK, Manser T, Howard SK, et al. Use of cognitive aids in a simulated anesthetic crisis. *Anesthesia & Analgesia* 2006; **103**: 551–6.
69. Picard J, Ward SC, Zumpe R, et al. Guidelines and the adoption of 'lipid rescue' therapy for local anaesthetic toxicity. *Anaesthesia* 2009; **64**: 122–5.
70. Phipps DL, Beatty PCW, Parker D, et al. Motivational influences on anaesthetists' use of practice guidelines. *British Journal of Anaesthesia* 2009; **102**: 768–74.
71. Tscholl DW, Weiss M, Kolbe M, et al. An anesthesia preinduction checklist to improve information exchange, knowledge of critical information, perception of safety, and possibly perception of teamwork in anesthesia teams. *Anesthesia & Analgesia* 2015; **121**: 948–56.
72. Toff B. External Inquiry into the adverse incident that occurred at Queen's Medical Centre, Nottingham, 2001. http://www.gatasm.org/sites/default/files/Brian%20Toft%20report.pdf (accessed 27/05/2017).
73. Walker IA, Griffiths R, Wilson IH. Replacing Luer connectors: still work in progress. *Anaesthesia* 2010; **65**: 1059–63.
74. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Annals of Emergency Medicine* 2012; **59**: 165–75.
75. Weingart SD, Trueger NS, Wong N, et al. Delayed sequence intubation: a prospective observational study. *Annals of Emergency Medicine* 2015; **65**: 349–55.
76. Mercer SJ, Jones CP, Bridge M, et al. A systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma. *British Journal of Anaesthesia* 2016; **117**(S1): i49–59.

3.2 Human Factors in Preventing Complications in Anaesthesia. Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. *Anaesthesia* 2018; 73(S1): 12-24

3.2.1 Why this paper was written?

This paper was written following an invitation from the editor of the journal *Anaesthesia* based on my previous publications and national reputation and was to be included in a patient safety supplement. I was also keen to summarise the current literature around human factors in the operating theatre, particularly for acute care, including trauma.

3.2.2 What was known at the time of writing?

At the time of writing (summer 2017) human factors in healthcare was starting to be relaunched. As described earlier in this thesis, initial interest around this subject commenced with the seminal papers '*To Err is Human'* (22) and *'An Organisation with a Memory'* (23). Despite these important documents, the human factors culture was not firmly established in healthcare and this was despite the introduction of the 'World Health Organisation Surgical Safety Checklist' (103). A number of key institutions signed up to a 'Concordat in Human Factors' (30) and it was hoped that this would renew interest and raise the profile of this aspect of healthcare

3.2.3 What the paper added or contributed to the 'global' clinical community?

One of the purposes of this thesis is to demonstrate that I have developed a national reputation in the field of human factors in complex trauma. I have used the knowledge discovered in this paper to develop lectures at the following invited national meetings

- **Simulation for Trauma Training.** Trauma Care Conference, Yarnfield Conference Centre, Stafford, 6 March 2019
- **Wrong Site Block,** Royal College of Anaesthetists Updates Meeting, Hilton Hotel, Liverpool, 26 November 2018
- **Improving Trauma Teams. Understanding Why Teams Don't Work,** Cambridge Trauma Conference, Churchill College Cambridge, 28 April 2018

- **Human Factors in Complex Trauma,** Association of Anaesthetists of Great Britain and Ireland Annual Congress, BT Convention Centre, Liverpool, 28 September 2017

3.2.4. Where are we now?

This article has been cited in the medical literature 14 times and has an Altmetric score of 269 (404 mentions on Twitter, citation in 2 blogs and 2 Facebook pages, also 67 Mendeley engagements). I have further used the basis of this publication to develop the following further publications.

- Team-working, communication and use of communication aids and checklists (Book Chapter). Mercer SJ. Chapter in *Section 2 - The impact of human factors in clinical practice in Decision-Making and Simulation in Obstetric Anaesthesia. Cambridge University Press.* 2019 Chapter 8 Pg 45-51
- Education Training and Human Factors. Mercer SJ, Khan M, Matthews JJ, Reavley P, Gurney I, Glover N, Jones CP. Military Medicine in Iraq and Afghanistan. A Comprehensive Review. Edited by Ian Greaves. 2019 Chapter 22: 485-509, CRC Press, Boca Raton, FL
- Followership in complex trauma. Fadden S, Mercer SJ *Trauma* 2019; **21**: 6-13

The following articles listed in Table 2.5 have also cited this publication (I have only listed articles in English)

Table 2.5 Articles citing Human Factors in Preventing Complications in Anaesthesia. Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. *Anaesthesia* 2018; 73(S1): 12-24

Paper	Summary
Loh LWW, Lee JSE, Goy RWL. Exploring the impact of overnight call stress on anaesthesiology senior residents' perceived ability to learn and teach in an Asian healthcare system: A qualitative study. *Trends in Anaesthesia and Critical Care* (In Press: Accepted 25 March 2019)	This project looked at acute stress in terms of senior residents in anaesthesia and explored the nature of the stressors, and their influence on trainees' perceived learning and teaching using focus groups. There were four different types of stressors identified which included emergency work, physical and mental exhaustion, concerns over supervisory roles and incurring clinical risks, and concerns with appearing deficient. Our article was cited as it was described that errors in anaesthesia have been attributed to deficiencies in non-technical skills. They also quoted that fatigue reduces vigilance, slows cognition, increases reaction time and worsens decision making abilities.
Ahmad I, El-Boghdadly K. From evidence based on practice to evidence-based practice: time for a difficult airway management research strategy. *Anaesthesia* 2019; 74: 135–139	This editorial discusses a proposed roadmap for the development of a difficult airway research strategy. Our article is cited in the context that critical incidents in airway management are often unpredicted and are associated with high levels of cognitive load and stress.

Barrington MJ, Lirk P. Reducing the risk of neurological complications after peripheral nerve block: what is the role of pressure monitoring? *Anaesthesia* 2019; 74: 9–12	This editorial discusses the introduction of pressure monitors for use when undertaking peripheral nerve blocks. Our article is cited in the context that it is important to provide education and core skills development to trainees and that non-technical skills such as situational awareness, adequate organisation, preparation and standardisation of processes using safety checklists are also important. These are issues that our discussed in our article.
Chrimes N, Marshall SD. Attempt XYZ: airway management at the opposite end of the alphabet. *Anaesthesia* 2018, 73, 1464–1468	Our article is cited in terms of fixation errors and it discusses the management of a difficult airway. The use of XYZ is to define the last three upper airway instrumentations before performing an emergency surgical airway. Fixation errors occur when the practitioner concentrates solely upon a single aspect of a case to the detriment of other more relevant aspects (104).
Chrimes N, Bradley WPL, Gatward JJ et al. Human factors and the 'next generation' airway trolley. *Anaesthesia* 2019; 74: 427–433	This article discusses the key principles for incorporating human factors into airway trolley design and implementation so as to enhance team performance. Our article is cited as a definition of human factors in terms of the operating theatre where anaesthetists must consider the impact of aspects of the individual, environment, processes and culture on human performance.
Evain JN, Perrot A, Vincent A, et al. Team planning discussion and clinical performance: a prospective, randomised, controlled simulation trial. *Anaesthesia* 2019; 74: 488–496	This study investigated whether a brief planning discussion improved team performance in a simulated critical care situation. The authors concluded that a 4-minute planning discussion before a simulated critical care situation improved clinical team performance and cognitive appraisal ratios. Our article is cited as it describes the importance of human factors in patient safety.
Evans DJR, Pawlina W, Lachman N. Human Skills for Human[istic] Anatomy: An Emphasis on Nontraditional Discipline-Independent Skills. *Anatomical Sciences Education* 2018; 11: 221–224	This article discusses human factors concerning anatomists. Out article is cited as a definition of human factors.
Greenland KB, Irwin MG. Big data: breaking new ground in airway research. *Anaesthesia* 2018: 73; 674–678	This article discusses analysis of cases of emergency front of neck access. Our article is cited to make reference to the case of Elaine Bromley who died as she did not receive this treatment.
Pavithran P, Rajesh MC, Rekha K. Survey of change in practice following simulation-based training in crisis management. *Indian Journal of Anaesthesia* 2018; 62: 991-994	This publication reviews the effectiveness of a simulation experience on management of crisis situations. Our article is cited to emphasise that human factors impact our efficiency and management which is a significant factor contributing to the medical errors.
Valchanov K, Sturgess J. Complications: an anaesthetist's rather than a surgeon's notes (with apologies to Atul Gwande). *Anaesthesia* 2018; 73(S1): 3–6	This is the editorial that introduces the journal article that our article is published in.
Barrington MJ, Lirk P. Reducing the risk of neurological complications after peripheral nerve block: what is the role of pressure monitoring? *Anaesthesia* 2019; 74: 9-12	This is an Editorial in the Journal of *Anaesthesia* looking at human factors and peripheral nerve blocks
Pavithran P, Rajesh MC, Rekha K,Sajid B. Survey of change in practice following simulation-	This article reported a survey among the anaesthetic participants of a simulation-based learning workshop, and

based training in crisis management. Indian Journal of Anaesthesia 2018; 62: 991–994.	investigated attitudes, change in knowledge and effects of the training on practice.
Casali G, Cullen W, Lock G. The rise of human factors: optimising performance of individuals and teams to improve patients' outcomes. *Journal of Thoracic Disease* 2019; 11(S7): S998-S1008	This is a theoretical paper that supports the adoption of a broader model of human performance as a function of technical and non-technical skills. It also looks at culture and organisation. Our article is cited as latent threats are predisposed to loss of situational awareness and poor decision-making

This article was also cited in the following thesis

Deniz Dishman

- **Title**: Adaptation and Validation of the Situation Awareness Global Assessment Technique for Student Registered Nurse Anesthetists (2019)
- **Institution**: Virginia Commonwealth University

Following publication of this paper I was invited to sit on the Royal College of Anaesthetists (RCoA) Simulation Steering Committee who have recently published their strategy that was approved by the RCoA Council (105).

3.2.5 Reflections on the methodology/method(s)

3.2.5.1 Literature review and article selection

Our full protocol and search strategy were registered with and published by PROSPERO (http://www.crd.york.ac.uk/PROSPERO). By registering with this organisation a peer review of our methodology was undertaken of the project and it was deemed to be acceptable and was registered on a national database to ensure transparency. Medline and CINAHL databases were searched and papers reporting on human factors and non-technical skills in anaesthesia were included with the search limited to articles published from the year 2000 onwards. The year 2000 as a cut off was chosen to reflect contemporary practice. The search included full-text reports of articles from peer-reviewed journals published in English with no restriction to study methodology. To ensure a comprehensive search, we manually searched anaesthesia-specific journals by typing 'human factors' into the search box for *Anaesthesia*, *Anesthesiology, Anesthesia & Analgesia, The British Journal of Anaesthesia, the Canadian Journal of Anesthesia* and *European Journal of Anesthesiology*, accepting articles (not

abstracts presented at conferences) from after 2000. Finally, in addition, reference lists of the manuscripts reviewed were scrutinised for additional relevant articles and book chapters. This ensured that the literature had been reviewed as comprehensively as possible.

The titles and abstracts of the references obtained from the database search were reviewed by two independent reviewers. The inclusion criteria being papers referring to human factors; non-technical skills; team resource or crew resource management; and papers published on or after 2000. Articles were removed if both reviewers agreed independently to exclude. In the event of agreement to include, or a discordant opinion, articles were reviewed in full by one out of five independent reviewers. The year 2000 was chosen to focus on recent practice and does exclude the seminal paper *'To Err is Human; Building A Safer Health System"* (22). This paper (22) does not directly refer to anaesthetic management in the operating theatre and its ideas and suggestions are mentioned in many subsequent papers. A limitation to this study was that a risk of bias assessment was not performed which could itself have led to a bias in the studies that were selected in the final paper.

This article summarises the literature around Human Factors in Anaesthesia particularly in dealing with a patient involved in complex trauma. Examples are cited of teamworking, communication, situational awareness and human error ending with a review of human factors in clinical practice looking at trauma. National guidelines and publications that are specifically mentioned include the following

- **Anaesthetists Non-Technical Skills (ANTS).** Work from a team at the University of Aberdeen has extensively reviewed how non-technical skills are classified for working as an anaesthetist (106,107). Similar frameworks have been devised for Surgeons (108) and Scrub Practitioners (36).
- **National Audit Project 4 (NAP4).** This National Audit Project was sponsored by the Royal College of Anaesthetists and the Difficult Airway Society (25). This article highlights the human factors elements that were noted in the final report including individual and system errors. Subsequent analysis of unanticipated difficult airways included in the report has further highlighted the importance of human factors in emergency airway management (66) and this can be translated to trauma.
- **National Audit Project 5 (NAP5).** This National Audit Project focused on awareness in anaesthesia. Human factors are discussed under induction, maintenance and emergence from anaesthesia (109).

Despite registering the systematic review methodology with the peer reviewed organisation PROSPERO (International Prospective Register of Systematic Reviews) (110) and searching two of the largest medical databases, there were still 16 journal articles that were missed in the initial search only to be found later in the process when mainstream anaesthesia journals were searched by hand or references in other articles were reviewed. I will discuss this further in section 3.3.5.

3.2.3 Summary

This systematic review summarises the recent literature on human factors related to anaesthesia. Two recent national audits have strongly commented on the importance of human factors in clinical practice. Our article described how human factors are important in the setting of complex trauma. This article has been useful to inform the anaesthetic community on the importance of human factors in anaesthesia.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma. Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P. *British Journal of Anaesthesia* 2016: 117 (S1): i49–i59

3. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (40%) Literature review, 1st draft of manuscript and subsequent drafts. CP Jones (20%) Literature review, subsequent drafts and mental model diagrams. M Bridge (5%) Literature Review. E Clitheroe (5%) Literature review. B Morton (10%) revision of manuscripts. P Groom (20%) original idea, literature review and subsequent drafts of manuscript.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
CP Jones		clintonpljones@hotmail.com
M Bridge		Matthew.Bridge@aintree.nhs.uk
E Clitheroe		edclitheroe@yahoo.co.uk
B Morton		benjmorton@doctors.org.uk
P Groom		petergroomx@yahoo.com

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	
	(Director of Studies/Advisor)		

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	
	(Director of Studies/Advisor)		

6. Signature of Faculty Research Degrees Administrator

Signature:		Date:	
	(Faculty Research Degrees Administrator)		

BJA

British Journal of Anaesthesia, 117 (S1): i49–i59 (2016)

doi: 10.1093/bja/aew193
Special Issue

Systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma

S. J. Mercer[1,2,3,*], C. P. Jones[1], M. Bridge[1], E. Clitheroe[1], B. Morton[1,4] and P. Groom[1]

[1]Anaesthetic Department, Aintree University Hospital NHS Foundation Trust, Longmoor Lane, Aintree, Liverpool L9 7AL, UK, [2]Defence Medical Services, Royal Centre for Defence Medicine, Queen Elizabeth Hospital Birmingham, Mindelsohn Way, Edgbaston, Birmingham B15 2WB, UK, [3]Postgraduate School of Medicine, University of Liverpool, Cedar House, Ashton Street, Liverpool L69 3GE, UK, and [4]Honorary Research Fellow, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, UK

*Corresponding author. E-mail: simonjmercer@hotmail.com

Abstract

Introduction: Non-iatrogenic trauma to the airway is rare and presents a significant challenge to the anaesthetist. Although guidelines for the management of the unanticipated difficult airway have been published, these do not make provision for the 'anticipated' difficult airway. This systematic review aims to inform best practice and suggest management options for different injury patterns.

Methods: A literature search was conducted using Embase, Medline, and Google Scholar for papers after the year 2000 reporting on the acute airway management of adult patients who suffered airway trauma. Our protocol and search strategy are registered with and published by PROSPERO (http://www.crd.york.ac.uk/PROSPERO, ID: CRD42016032763).

Results: A systematic literature search yielded 578 articles, of which a total of 148 full-text papers were reviewed. We present our results categorized by mechanism of injury: blunt, penetrating, blast, and burns.

Conclusions: The hallmark of airway management with trauma to the airway is the maintenance of spontaneous ventilation, intubation under direct vision to avoid the creation of a false passage, and the avoidance of both intermittent positive pressure ventilation and cricoid pressure (the latter for laryngotracheal trauma only) during a rapid sequence induction. Management depends on available resources and time to perform airway assessment, investigations, and intervention (patients will be classified into one of three categories: no time, some time, or adequate time). Human factors, particularly the development of a shared mental model amongst the trauma team, are vital to mitigate risk and improve patient safety.

Key words: airway management; blast injuries; blunt injuries; burns; wounds, penetrating

Trauma to the airway may cause acutely life-threatening airway laceration, obstruction, haemorrhage, and aspiration of blood; this presents the anaesthetist with a major challenge.[1 2] Fortunately, airway trauma is a relatively infrequent complication of major trauma, in both the UK civilian (National Health Service) and UK Defence Medical Services settings.[3 4] However, complications related to this injury can be catastrophic without optimal management. For example, in a patient with blunt or penetrating airway trauma, advancing a bougie or tracheal tube blindly beyond the vocal cords risks penetration through an airway laceration, leading to airway obstruction, pneumomediastinum, and the creation of a false passage.[1 5] Guidelines for the management of the unanticipated difficult airway have recently been revised by the Difficult Airway Society;[6] however, these do not make provision for an 'anticipated' difficult airway that could be experienced in complex trauma, and if followed, could even worsen

Accepted: May 23, 2016

the traumatic airway. Our aim was to inform best practice for airway trauma and suggest management options for the various injury patterns to reduce serious sequelae.

Methods

Search strategy

We searched Embase, Medline, and Google Scholar for papers reporting on the acute airway management of adult patients who had suffered airway trauma. We limited the search to articles published from the year 2000 onwards to represent contemporary practice. The search included full-text reports of articles from peer-reviewed journals and conference abstracts published in English, and there were no restrictions to the studies reviewed. In addition, the reference lists of the articles reviewed were scrutinized for additional relevant articles and book chapters.

Article selection

Titles and abstracts of the references obtained were reviewed by two independent reviewers (M.B. and C.P.J.). Articles were categorized for inclusion or exclusion. Articles were removed if both reviewers agreed independently to exclude. In the event of agreement to include or a discordant opinion, articles were reviewed in full by one of four independent reviewers (C.P.J., P.G., E.C., and S.J.M.). Inclusion criteria were as follows: adults older than 18 yr of age with airway trauma; papers published on or after 2000; and papers reporting airway trauma (blunt, burn, penetrating, blast, or miscellaneous injuries) and anaesthetic management. The exclusion criteria were as follows: children (<18 yr old); animal studies; papers not dealing with acute trauma and airway trauma; and papers that did not have an airway management focus. Our full protocol and search strategy are registered with and published by PROSPERO (http://www.crd.york.ac.uk/PROSPERO, ID: CRD42016032763); this includes the search terms and keywords used.

Results

Our systematic literature search yielded 578 articles (see Fig. 1). Two hundred and sixteen were excluded after title review. After abstract review, a further 214 articles were excluded. A total of 148 full-text papers were reviewed, of which we included 35 in this review. Figure 1 details reasons for inclusion and exclusion. We present our results categorized by mechanism of injury, as follows: blunt, penetrating, blast, and burns.

Blunt injury

Blunt airway trauma usually involves high-energy transfer; examples include assault, crush, fall from height, road traffic collision, pedestrian *vs* vehicle, hanging, accidental strangulation, and the 'clothesline' mechanism. Table 1 describes the various mechanisms of injury in blunt trauma and their associated injuries.

Patients who suffer blunt injury develop complex airway injuries, often as part of severe multisystem trauma. Failure to intubate, secure, and protect the airway in these patients are common factors that lead to an increase in morbidity and mortality.[7–9] Blunt airway trauma includes maxillofacial trauma, laryngotracheal trauma (LTT), and disruption of the trachea and bronchi. The sternum, cervical spine, and mandible shield the airway during trauma such that the incidence of blunt airway injury is low (~0.4%).[7–9] Despite being a rare pathology, the impact can be significant, with mortality rates of traumatic lesions below the vocal cords quoted as high as 63%.[10] Bronchial disruption occurs in 1% of chest trauma; most of these patients die at the scene.[11]

Maxillofacial trauma is the most common type of blunt airway trauma but does not usually present a problem because trismus is usually attributable to pain and therefore resolves on induction. The main issues to consider are then airway haemorrhage, hypoxia, and the risk of aspiration. Very rarely, trismus is the result of impaction of a condylar head fracture, causing a physical obstruction to mouth opening, which becomes apparent only after rapid sequence induction.[12]

The cricoid cartilage and cricothyroid membrane are involved in 50% of instances of blunt airway trauma with airway compromise; injury to the thyrohyoid membrane, thyroid cartilage, and extrathoracic trachea account for the remainder.[1 13] Laryngotracheal separation occurs in up to 63% of instances, usually between the cricoid and fourth tracheal cartilage.[14 15] The airway can remain patent if spontaneous respiration is maintained by splinting of peritracheal connective tissue.[16] This situation is precarious and can deteriorate rapidly.[17]

Blunt trauma at the level of the larynx or below can be difficult to diagnose and life threatening if managed poorly. Patients can present with non-specific signs and symptoms, such as cough, dyspnoea, aphonia, stridor, laryngeal crepitus, haemoptysis, and subcutaneous emphysema. These symptoms do not correlate well with the anatomical site of the lesion;[14 15] however, complaints of haemoptysis and stridor at presentation have been associated with severity of injury.[16 18]

In view of the poor relation between signs and severity of injury, the clinician must have both a high index of suspicion and a low threshold for further investigations, including plain X-rays (chest and lateral cervical spine) to rule out surgical emphysema, pneumothorax, or both. Nasendoscopy is useful and permits assessment of vocal cord movement, integrity of the laryngeal mucosa, and airway patency.[13] Computed tomography is the gold standard and detects the site of injury in 94% of blunt trauma.[19] Bronchoscopy is considered the best diagnostic tool for suspected lesions below the vocal cords,[11 14 20] but utility in acute airway compromise is limited because it is a skilled technique and access to equipment may be limited. The severity of blunt airway trauma has been classified by Schaefer and Close[21] (Table 2).

Trauma to the upper and lower respiratory tract should be managed on a patient-by-patient basis. Minor instances of blunt airway trauma should be observed in the critical care unit, with reassessment of the airway at regular intervals for at least 48 h. The management of major blunt airway trauma is governed by the degree of patient cooperation and a risk–benefit analysis. The safest approach to patients requiring intubation is to instrument the trachea under direct vision to avoid entering a tear, creating a false passage, or disrupting the airway completely.[1] It is preferable to do this with the patient awake and breathing spontaneously.

Following these principles, there are three judicious approaches to airway management . First, performing an awake tracheostomy under local anaesthesia is a common intervention of choice for LTT.[18] However, this technique requires a high degree of operator skill, may be difficult, and is limited by patient cooperation and teh time taken to assemble skilled assistance.[16 22 23] It is important to note that surgical cricothyroidotomy and percutaneous cricothyroidotomy are contraindicated in these patients because they may lead to further airway disruption.[11 18 24] This is not the case for tracheobronchial trauma because the lesion is commonly more distal, with 76% of injuries occurring within 2 cm of the carina, and 43% occurring within the first 2 cm of the right main bronchus.[25 26]

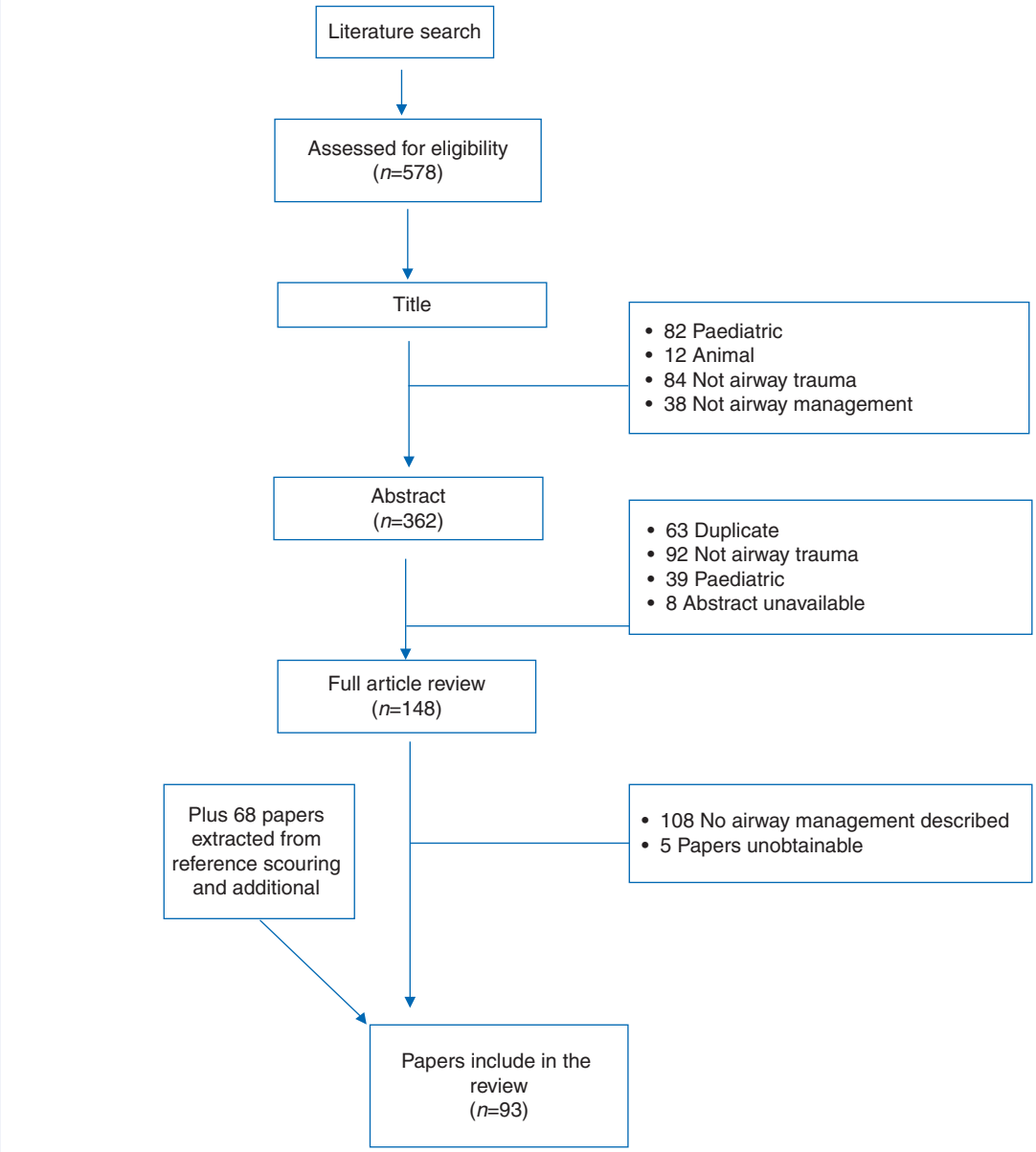


Fig 1 Systemic review literature search flow chart.

Second, awake fibreoptic intubation is an alternative technique, which maintains spontaneous ventilation and allows simultaneous airway assessment and placement of a tracheal tube distal to any pericarinal defect.[22 23] Care must be taken when railroading the tracheal tube so that its bevel does not catch on a tear, extending the injury.[27] This can be avoided by using a lubricated small-diameter tube, fitting snuggly onto the scope, and twisting the tube so that its bevel faces any lesion during its advancement into the trachea. The use of the Lightwand in blunt trauma has also been described.[28]

Third, conventional intubation is a rapid way of securing the airway but risks intubating a tear, creating a false passage, or disruption of the larynx or trachea.[21 29] Consequently, we recommend fibrescope-assisted direct or videolaryngoscopy as part of a modified rapid sequence induction (with no cricoid pressure or positive pressure ventilation because both may aggravate the injury).[30 31] A small-diameter tracheal tube should be placed at the introitus of the larynx under direct vision, and then a fibrescope is passed through the tube and into the trachea. The tracheal tube can then be delivered past the lesion safely if the bevel is orientated to face the lesion. Modified rapid sequence induction and rigid bronchoscopy is an alternative choice, because airway inspection is simultaneous with intubation. This technique requires a high degree of operator skill and needs appropriately trained personnel but can deal effectively with distal tracheal or bronchial disruption.[11 18 32] A summary of the associated problems and cautions in relation to the anatomical territory is presented in Table 3. The technique of choice depends upon the patient's condition, urgency, and the experience of the anaesthetist and surgeon.[33]

Table 1 The mechanisms of injury associated with blunt trauma to the airway[7]

Type of trauma	Mechanisim of injury	Airway injury
Road traffic collision	Severe flexion/extension	Tracheal tears
Fall	Rapid deceleration	Fractures of the larynx Laryngotracheal separation
Hanging Accidental strangulation 'Clothesline' mechanism Assault	Direct blows	Fractured thyroid or cricoid cartilages, or both Layrngotrachael separation
Crush	Crush injuries to chest	Tracheobronchial disruption
Pedestrian *vs* vehicle	Sudden, explosive increase in intrathoracic pressure against a relatively closed glottis	
	Rapid deceleration shears airways at fixed points: cricoid cartilage and carina	Transection at carina or cricotracheal junction
	Pulmonary compression tears the airway at the level of the carina	Carinal tear

Table 2 Classification of the severity of blunt airway injury (adapted from Schaefer and Close)[21]

Group 1	Minor endolaryngeal haemotoma, laceration, or both No detectable laryngeal fracture
Group 2	Laryngeal oedema, haemotoma, or both Minor mucosal disruption, but no exposed cartilage
Group 3	Massive oedema, large mucosal lacerations, exposed cartilage, displaced fracture, vocal cord immobility
Group 4	As group 3 plus comminuted or unstable fracture

Penetrating and blast injury

Penetrating injuries to the face and neck are uncommon in both civilian[25 34] and military[3 35] populations. However, the incidence is increasing in military personnel because modern body armour does not protect the face and neck.[26 34 36–38] Airway wounds can cause immediate life-threatening compromise[34] because of the density of vital structures within the neck.[1 2 39 40] Indeed, on exploration, a clinically superficial stab wound may reveal a vascular or aerodigestive injury.[3 4 32] Blast-induced injuries result from direct or indirect exposure to an explosion and have high potential for an associated upper airway injury,[5 34 41] the most severe of which is complete disruption of the airway.[1 35 42]

The causes of penetrating airway trauma are diverse and include assault or self-inflicted injuries with firearms or knives.[36–38 40] Facial wounds are usually the result of gunshot[2 7 9 38 39 43–45] or blast injuries.[4 10 46–53] Objects or projectiles can transfix the mouth and limit mouth opening.[11–15 25 34 40–45 54 55] Patients may also present with neck lacerations and open wounds to the airway.[2 16 38 40] Gunshot and blast injuries result in penetrating neck trauma,[25 46–53] so the clinician must always consider the likely trajectory of projectiles or fragments and their potential airway effects. The location of great vessels in the neck adjacent to the airway means that haemorrhage can impact airway patency,[14 15 54 56] with high mortality.[16 18 34 43 44 45 54]

When assessing these patients, an effective approach is to divide the structures of the head and neck into three zones.[13 39 55] Zone 1 is from the clavicles to the cricoid cartilage, zone 2 from the cricoid cartilage to the angle of the mandible, and zone 3 from the angle of the mandible to the base of the skull. Zone analysis predicts potential injuries and the need for urgent airway management solutions.[5 19 25] Blood loss and upper airway obstruction are the major determinants of injury severity.[14 38 40]

Wounds in the anterior and lateral aspects of the neck compromise the airway more often than those in the posterior region.[11 20 25 40 42] The clinician should also consider the presence of blood and debris within the lumen of the airway, injury within the airway wall itself, or injury outside the wall (e.g. expanding haematoma or surgical emphysema). If possible, computed tomography is the first-line investigation in stable patients with penetrating neck injuries[21 35 56] in order to identify the location of an airway injury.

As with blunt injuries, major penetrating and blast airway trauma management is governed by the degree of patient cooperation and a risk–benefit analysis. Potential difficulties to consider are neck haematoma or subcutaneous emphysema around the airway that can distort anatomy and impair tracheostomy. Fibreoptic intubation is difficult if blood or debris is present within the airway. Regardless, awake fibreoptic intubation in skilled hands has proved effective.[1 18 39 41 43–45 54 57]

The literature suggests that the safest approach to patients requiring intubation is to instrument the trachea under direct vision in order to avoid entering a tear, creating a false passage, or disrupting the airway completely.[5 16 22 23 50 58] It is preferable to do this with the patient awake and breathing spontaneously. Similar to blunt trauma, awake tracheostomy is the intervention of choice,[5 11 18 22 23 25 26 35 38 40 42 59–64] and surgical or percutaneous cricothyroidotomy are contraindicated.[27 59] It is important to consider thoracotomy if a patient presents with chest trauma, and low tracheal or bronchial transection standard tracheostomy in this situation will result in malposition distal to the defect. Awake fibreoptic intubation is an alternative option to permit simultaneous airway assessment and placement of a tracheal tube distal to any laceration.[21 29 41 45 57 65 66] As emphasized already, great care must be taken when railroading the tracheal tube so that its bevel does not extend a laceration. A modified

Table 3 A summary of the the associated problems and cautions in relation to the anatomical territory in blunt injury. LTT, laryngotracheal trauma

	Anatomical territory	Associated problems	Caution: red flag signs and symptoms
	Maxillofacial	Traumatic brain injury and base of skull fracture Cervical spine fracture Ophthalmic injury Vascular injury Aspiration of blood and debris	Signs of elevated intracranial presssure Neurological deficit Neurogenic shock Significant bleeding from fracture displacement Bilateral anterior mandible fractures and airway obstruction Ventilatory failure
	Laryngotracheal	Cervical fracture Vascular injury Oesophageal injury Rib fractures and flail segment Pneumothorax Haemothorax Pneumomediastinum Pulmonary contusion	Haemoptysis and stridor have previously been reported as cardinal features of severe LTT Massive surgical emphysema Ventilatory failure Cardiovascular collapse
	Trachea and bronchi	Vascular injury Oesophageal injury Rib fractures and flail segment Pneumothorax Haemothorax Pneumomediastinum Pulmonary contusion	Haemoptysis Massive surgical emphysema Ventilatory failure Cardiovascular collapse

rapid sequence induction and fibreoptic-assisted direct or videolaryngoscopy may be undertaken if a general anaesthetic must be administered immediately. However, the clinician should avoid neuromuscular blocking agents (muscle tone may be important for airway integrity in airway transection)[30 50 58 67] and be cognizant that conventional intubation risks intubating a tear.[5 31 68] We suggest that this may be mediated by fibrescope-assisted direct or videolaryngoscopy as part of a modified rapid sequence induction (with no cricoid pressure or positive pressure ventilation). A tracheal tube should be placed above the vocal cords under direct vision and then a fibrescope passed through the tube and into the trachea. The tracheal tube can then be delivered safely as described above. Large neck wounds can be intubated directly over a fibrescope in this manner. Combined usage of an Airway Scope and gum elastic bougie for emergency airway management in a patient with a neck stab wound has also been described,[69] as has the use of the AirTraq in traumatic asphyxiation,[70] and the use of the Lightwand.[28] A summary of the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by penetrating injury is presented in Table 4.

Burns

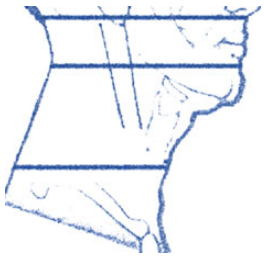
Burns to the upper airway caused by direct heat and steam injury, electrocution, or contact with corrosive chemicals can lead to marked swelling of the face, tongue, epiglottis, and glottis and result in airway obstruction.[11 18 25 32 34 60–64 71] Airway swelling may not occur immediately but may develop over a period of hours (exacerbated by fluid resuscitation). Therefore, a high index of suspicion and frequent re-evaluation of the airway are essential.[3 35 65 72–74] Thermal injury is primarily restricted to structures above the vocal cords, unless steam is inhaled, because the oropharynx and nasopharynx act as an efficient heat sink.[26 34 36–38 66 74] Smoke inhalation delivers a pathological insult to the lungs as a result of the particulates, respiratory irritants, and systemic toxins that it contains.[34 75] In this context, it is necessary to look for and treat carbon monoxide[76] and cyanide poisoning.[77]

Inhalation injury is a greater contributor to overall morbidity and mortality than either body surface area percentage or age[57 67] and is present in 60% of central facial burns.[61 68] Burns patients without smoke inhalation have a mortality of 2%, compared with a mortality of 30% with this type of injury.[78]

Patients who present acutely with facial and neck burns have two predominant airway issues: airway obstruction and smoke inhalation. These risks prompt the early intubation of high-risk patients,[75 79 80] because the rate of difficult intubation increases from 11.2 to 16.9% if delayed (owing to the development of airway oedema).[61 62 71 81] However, intubation is not without risk, and the clinician should carefully evaluate individual patients.[72–74 82] Nasendoscopy is an important tool to diagnose the extent and severity of an airway burn, and serial nasendoscopy of vocal fold oedema has been used to predict the need for intubation in patients at risk.[66 74] Fibreoptic bronchoscopy supports the diagnosis of smoke inhalation and may reveal carbonaceous debris, erythema, or ulceration.

Intubation is mandated in instances of heat and smoke inhalation injury combined with facial, neck, or extensive body burns. In contrast, physiologically stable patients with smoke inhalation injury but no facial or neck burns may be monitored by nasal endoscopy and intubated later.[57] In addition to airway oedema, other causes of difficulty include limited mouth opening and intractable trismus in electrical burns.[61] Mask ventilation may also be challenging because of the presence of dressings and exudates,[42 78] and the application of nasal oxygen should be

Table 4 A summary of the the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by penetrating injury

	Anatomical territory	Associated problems	Caution: red flag signs and symptoms
	Zone 3	Cranial nerve injury Oesophageal injury Vascular injury (to branches of the external carotid artery, internal carotid artery, vertebral artery, and internal jugular and facial veins)	Neurological deficit Neurogenic shock Odynophagia Haematemesis Air bubbling from wound
	Zone 2	Oesophageal injury Vascular injury (to common carotid, carotid bifurcation, vertebral arteries, and jugular veins)	Massive surgical emphysema Expanding or pulsatile haematoma Active bleeding Cardiovascular collapse
	Zone 1	Oesophageal injury Vascular injury (to subclavian and innominate vessels, common carotid and lower vertebral arteries, and jugular veins)	Haemoptysis

considered. This can significantly boost the effective inspired oxygen and can be left on during tracheal intubation attempts. The application of additional nasal oxygen during intubation has been termed NO DESAT).[83]

For an anticipated difficult airway, clinical examination and nasendoscopy will provide vital information; however, this does depend on the degree of patient cooperation and the severity of the injury. Minor injuries can be managed conservatively in a monitored (high-dependency unit) setting. For major burns requiring immediate treatment, for cooperative patients awake fibreoptic intubation should be considered if the preoperative evaluation reveals concern for upper airway patency or difficult mask ventilation.[79] For severe injuries or non-compliant patients, a primary surgical airway is mandated.[61 62 81] Tracheostomy may also be indicated if a laryngeal injury is suspected.[82 84] In uncooperative patients or those with less severe pathology on clinical examination and nasendoscopy, rapid sequence induction followed by videolaryngoscopy is appropriate. One article described the use of the Combitube in the airway management of burns patients.[85]

After intubation, the tube should be secured carefully because accidental extubation may have fatal consequences.[86] Fixation methods include wiring the tube to a tooth and the use of archbars. The tracheal tube should be left uncut because facial swelling can cause it to retreat into the oropharynx, requiring re-intubation at the worst possible time. A summary of the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by burn injuries is presented in Table 5.

Conclusion

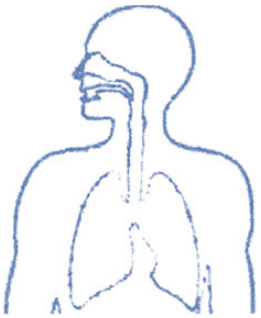
Our systematic review of the literature on acute adult non-iatrogenic airway trauma has highlighted common themes that should guide the clinician. The hallmark of airway management in these patients is the maintenance of spontaneous ventilation if at all possible, intubation under direct vision to avoid the creation of a false passage, and the avoidance of both intermittent positive pressure ventilation and cricoid pressure during a rapid sequence induction. This situation is distinct from the management of an unanticipated difficult airway. Here, adherence to the Difficult Airway Society 2015 guidelines[6] could even worsen the situation in this patient population because cricoid pressure, positive pressure ventilation either via a face mask or a supraglottic airway device, and surgical cricothyroidotomy are all contraindicated.

Consequently, if the primary intubation plan fails, there is only one rescue plan to avoid making the situation worse, namely surgical tracheostomy. The management of burns patients is broadly similar but with the caveat that the Difficult Airway Society 2015 guidelines[6] apply throughout because the clinician is not faced with the problem of an airway laceration or transection.

Ultimately, when considering all these types of airway traumas, the clinician is faced with a time-management issue, with a patient being classified into one of three groups: no time, some time, or adequate time for airway assessment, investigation, and intervention. If the patient is in extremis and there is no time for assessment, the anaesthetist must manage the patient urgently while planning for the worst-case scenario; a false passage in blunt, penetrating, and blast trauma, for example. If the airway appears stable then there is adequate time for assessment, planning, and intervention in optimal conditions. Most patients are somewhere between these two extremes, such that informed decision making is crucial for the anaesthetist because the situation can be worsened or stabilized by their subsequent actions. For example, allowing a patient to assume their most comfortable position, be that sitting, lateral, or prone, may 'buy enough time' to undertake nasal endoscopy or computed tomography.[4] Objects that impale the patient should be trimmed carefully so they do not impede subsequent airway interventions.[42 87] Finally, location is very important; it could be safer to transfer the patient to theatre to secure the airway, especially if a tracheostomy is required, because there is more space, better lighting, and staff more familiar with the intervention.

Human factors are key to the management of a complex anticipated airway problem.[88 89] The recently revised Difficult Airway Society Guidelines for the management of an unanticipated difficult airway[6] devote a significant section to these. Leadership, followership, teamwork, and situational awareness and communication amongst the team are all vital to ensure that the airway is safely secured. A trauma team will often have 10–15 min to prepare to receive a patient once they have been activated.[84] During this period, the anaesthetist should consider the likelihood of airway trauma and the possible investigations

Table 5 A summary of the the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by burn injuries

	Anatomical territory	Associated problems	Caution: red flag signs and symptoms
	Face, tongue, and oropharynx	Pulmonary oedema Cardiovascular dysfunction Carbon monoxide and cyanide poisoning	Evidence of thermal or chemical injury to face, lips, mouth, pharynx, or nasal mucosa Inflammation, blistering, oedema, and mucosal lesions Hair singeing Soot in mouth
	Larynx		Stridor Hoarseness
	Trachea, bronchi, and distal airways		Carbonaceous sputum Dyspnoea Hypoxaemia Increased concentrations of carbon monoxide and cyanide may not cause cyanosis Decreased level of consciousness, confusion, or signs of cerebellar dysfunction Mortality increases significantly with inhalation injury
Ensure primary survey completed to assess for other traumatic injuries Avoid task fixation with burns			

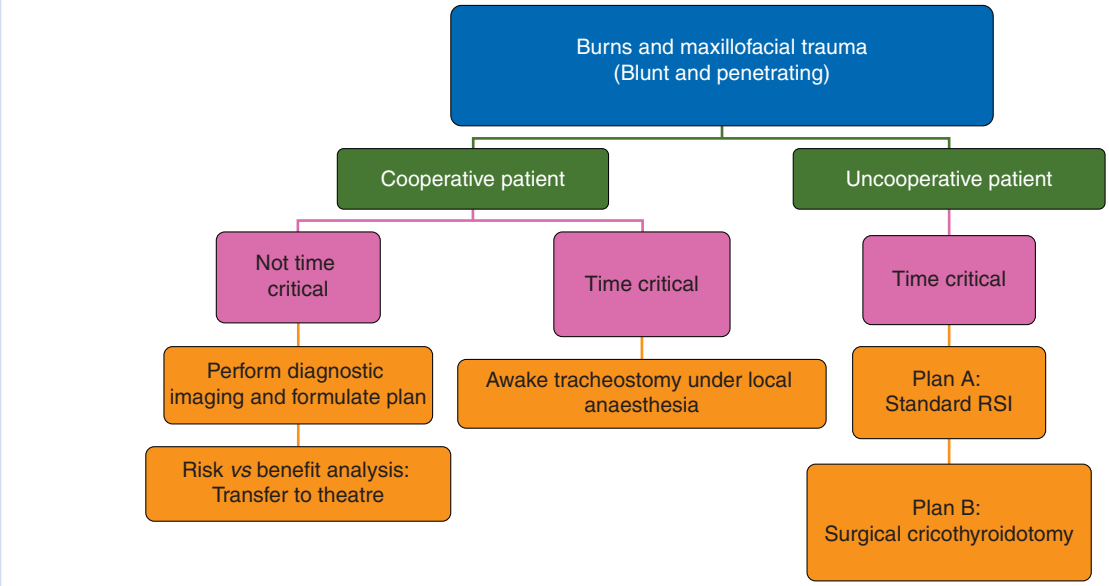


Fig 2 An example of shared mental model maps for burns and maxilliofacial trauma. RSI, rapid sequence induction.

and airway interventions required. This includes consideration of what personnel and equipment are needed and specifically who will perform a tracheostomy or surgical cricothyroidotomy if required. The UK Defence Medical Services have developed the concept of a 'command huddle',[90] where decisions are made by a senior team about further management after the primary survey. A conversation around airway management (if it has not already taken place) should occur here, with a discussion around the airway technique of choice.

The majority of anaesthetists have limited exposure to complex airway trauma and need to develop shared mental models to optimize management techniques; examples of these are included in Figs 2 and 3. Our review presents contemporary evidence in management of airway trauma to inform clinical practice. The clinician should also consolidate knowledge through mechanisms such as high-fidelity simulation scenarios[91] and by attending workshops specifically for the management of airway trauma.

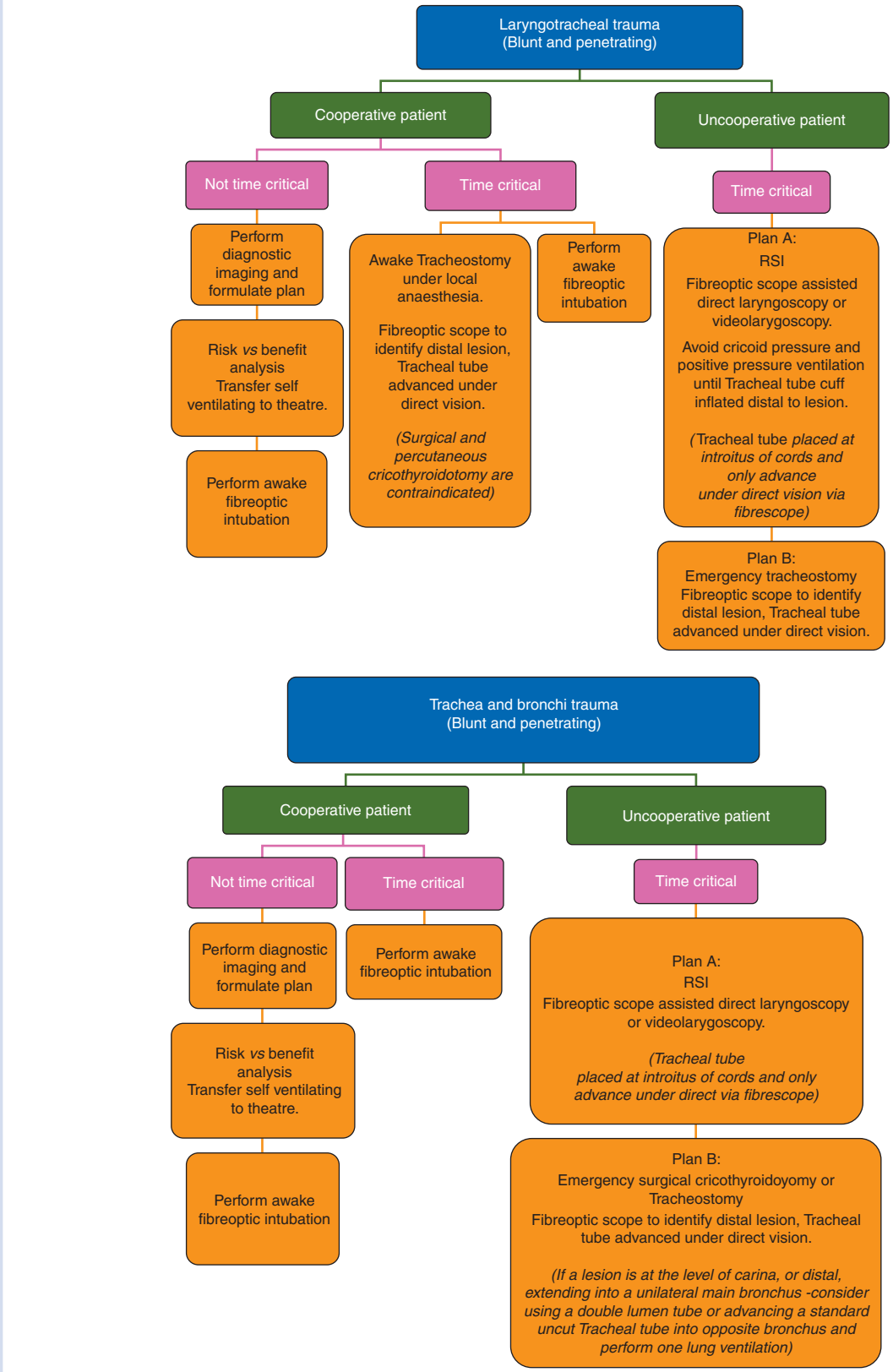


Fig 3 A shared mental model map for laryngotracheal trauma (blunt and penetrating). RSI, rapid sequence induction.

Authors' contributions

Substantial contributions to the conception or design of the work: B.M., S.J.M., P.G.
Acquisition of data: S.J.M., P.G., M.B., C.P.J., E.C.
Analysis of data: B.M., S.J.M., P.G., M.B., C.P.J., E.C.
Interpretation of data: B.M., S.J.M., P.G., M.B., C.P.J., E.C.
Drafting work for important intellectual content: B.M., S.J.M., P.G., C.P.J.

Declaration of interest

B.M. has received an honorarium for a lecture by Grifols, Inc.; this represents no conflict of interest for the submitted manuscript. S.J.M., C.P.J., M.B., E.C. and P.G. have no conflict of interest to declare.

References

1. Gussack GS, Jurkovich GJ, Luterman A. Laryngotracheal trauma: a protocol approach to a rare injury. *Laryngoscope* 1986; **96**: 660–5
2. Bhattacharya P, Mandal MC, Das S, Mukhopadhyay S, Basu SR. Airway management of two patients with penetrating neck trauma. *Indian J Anaesth* 2009; **53**: 348–51
3. Breeze J, Gibbons AJ, Shieff C, Banfield G, Bryant DG, Midwinter MJ. Combat-related craniofacial and cervical injuries: a 5-year review from the British military. *J Trauma* 2011; **71**: 108–13
4. Mercer S, Lewis S, Wilson S, Groom P, Mahoney P. Creating airway management guidelines for casualties with penetrating airway injuries. *J R Army Med Corps* 2010; **156**: S355–60
5. Abernathy JH 3rd, Reeves ST. Airway catastrophes. *Curr Opin Anaesthesiol* 2010; **23**: 41
6. Frerk C, Mitchell VS, McNarry AF, *et al*. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**: 827–48
7. Mohan R, Iyer R, Thaller S. Airway management in patients with facial trauma. *J Craniofac Surg* 2009; **20**: 21–3
8. Kummer C, Netto FS, Rizoli S, Yee D. A review of traumatic airway injuries: potential implications for airway assessment and management. *Injury* 2007; **38**: 27–33
9. Gruen RL, Jurkovich GJ, McIntyre LK, Foy HM, Maier RV. Patterns of errors contributing to trauma mortality: lessons learned from 2594 deaths. *Ann Surg* 2006; **244**: 371
10. Bhojani RA, Rosenbaum DH, Dikmen E, *et al*. Contemporary assessment of laryngotracheal trauma. *J Thorac Cardiovasc Surg* 2005; **130**: 426–32
11. Kayani AG, Pervaiz AA, Umair B, Siddique K, Khalique K. Right main bronchial disruption due to blunt trauma. *J Col L Physicians Surg Pak* 2009; **19**: 249–51
12. Smith CE, Fallon WF. Sevoflurane mask anesthesia for urgent tracheostomy in an uncooperative trauma patient with a difficult airway. *Can J Anaesth* 2000; **47**: 242–5
13. Francis S, Gaspard DJ, Rogers N, Stain SC. Diagnosis and management of laryngotracheal trauma. *J Natl Med Assoc* 2002; **94**: 21
14. Valerio P, Ivan M, Francisco R, *et al*. Survival after traumatic complete laryngotracheal transection. *Am J Emerg Med* 2008; **26**: 837.e3–.e4
15. Lee WT, Eliashar R, Eliachar I. Acute external laryngotracheal trauma: diagnosis and management. *Ear Nose Throat J* 2006; **85**: 179–84
16. Peadey C. Initial airway management of blunt upper airway injuries: a case report and literature review. *Australas Anaesthesia* 2005. Available at: http://www.anzca.edu.au/documents/05_peady.pdf (accessed 24 June 2016)
17. Edwards WH Jr, Morris JA Jr, DeLozier JB 3rd, Adkins RB Jr. Airway injuries. The first priority in trauma. *Am Surg* 1987; **53**: 192–7
18. Akhtar S, Awan S. Laryngotracheal trauma: its management and sequelae. *J Pak Med Assoc* 2008; **58**: 241–3
19. Scaglione M, Romano S, Pinto A, Sparano A, Scialpi M, Rotondo A. Acute tracheobronchial injuries: impact of imaging on diagnosis and management implications. *Eur J Radiol* 2006; **59**: 336–43
20. Shimizu J, Hirano Y, Ishida Y, Kinoshita T, Tatsuzawa Y, Kawaura Y. Use of a silicone T-tube for management of a tracheal injury in a patient with cervical blunt trauma. *Jpn J Thorac Cardiovasc* 2003; **51**: 541–4
21. Schaefer SD, Close LG. Acute management of laryngeal trauma update. *Ann Otol Rhinol Laryngol* 1989; **98**: 98–104
22. Perdikis G, Schmitt T, Chait D, Richards AT. Blunt laryngeal fracture: another airbag injury. *J Trauma Acute Care Surg* 2000; **48**: 544–6
23. Demetriades D, Velmahos GG, Asensio JA. Cervical pharyngoesophageal and laryngotracheal injuries. *World J Surg* 2001; **25**: 1044–8
24. Atkins BZ, Abbate S, Fisher SR, Vaslef SN. Current management of laryngotracheal trauma: case-report and literature review. *J Trauma Acute Care Surg* 2004; **56**: 185–90
25. Desjardins G, Varon AJ. Airway management for penetrating neck injuries: the Miami experience. *Resuscitation* 2001; **48**: 71–5
26. Kiser AC, O'Brien SM, Detterbeck FC. Blunt tracheobronchial injuries: treatment and outcomes. *Ann Thorac Surg* 2001; **71**: 2059–65
27. Wu M-H, Tsai Y-F, Lin M-Y, Hsu I-L, Fong Y. Complete laryngotracheal disruption caused by blunt injury. *Ann Thorac Surg* 2004; **77**: 1211–5
28. Jain S, Bhadani U. Lightwand: a useful aid in faciomaxillary trauma. *J Anesth* 2011; **25**: 291–1
29. Fuhrman GM, Stieg FH 3rd, Buerk CA. Blunt laryngeal trauma: classification and management protocol. *J Trauma Acute Care Surg* 1990; **30**: 87–92
30. Cicala RS, Kudsk KA, Butts A, Nguyen H, Fabian TC. Initial evaluation and management of upper airway injuries in trauma patients. *J Clin Anesth* 1991; **3**: 91–8
31. Gold SM, Gerber ME, Shott SR, Myer CM. Blunt laryngotracheal trauma in children. *Arch Otolaryngol Head Neck Surg* 1997; **123**: 83–7
32. Nabeel A, Irfan M. Near fatal fall complicated by penetrating neck injury with uneventful outcome: a case report. *Bangladesh J Med Sci* 2011; **10**: 125–8
33. Mohammed S, Biyani G, Bhatia PK, Chauhan DS. Airway management in a patient with blunt trauma neck: a concern for anesthesiologist. *Eg J Anaest* 2014; **30**: 431–3
34. Keller W, Han P, Galarneau R, Brigger T. Airway management in severe combat maxillofacial trauma. *Otolaryngol Head Neck* 2015; **153**: 532–7
35. Kumar V, Kumar P, Prasad V, *et al*. Blast injury face: an exemplified review of management. *Natl J Maxillofac Surg* 2013; **4**: 33–9
36. Sheffy N, Chemsian RV, Grabinsky A. Anaesthesia considerations in penetrating trauma. *Br J Anaesth* 2014; **113**: 276–85
37. Daniel Y, de Regloix S, Kaiser E. Use of a gum elastic bougie in a penetrating neck trauma. *Prehosp Disaster Med* 2014; **29**: 212–3

38. Ezeanolue BC. Management of the upper airway in severe cut-throat injuries. *Afr J Med Med Sci* 2001; **30**: 233–5
39. Glapa M, Kourie JF, Doll D, Degiannis E. Early management of gunshot injuries to the face in civilian practice. *World J Surg* 2007; **31**: 2104–10
40. Mohan S, Varghese G, Kumar S, Subramanian DP. Penetrating facial injury by a wooden log. *Natl J Maxillofac Surg* 2014; **5**: 228–31
41. Takaki S, Yamaguchi O, Morimura N, Goto T. Self-inflicted oral penetration injury: an intravenous drip pole advanced from the mouth to the retroperitoneum. *Int J Surg* 2015; **16**: 112–5
42. Shetty S, Gupta S, BalasubramanyaHasan, Cherian S, Srikrishna M. Facio-cervical transfixion by a metallic rod: a case report. *Am J Otolaryngol* 2001; **22**: 160–3
43. Dobson GT. Airway management in a patient with a nail-gun injury to the floor of the mouth. *Ulster Med J* 2000; **69**: 148–51
44. Ban LH, Leone M, Visintini P, *et al*. Craniocerebral penetrating injury caused by a spear gun through the mouth. *J Neurosurg* 2008; **108**: 1021–3
45. Joly L-M, Oswald AM, Disdet M, Raggueneau JL. Difficult endotracheal intubation as a result of penetrating cranio-facial injury by an arrow. *Anesth Analg* 2002; **94**: 231–2
46. Sari M, Baylancicek S, Inanli S. Atypical penetrating laryngeal trauma: a bullet in the larynx. *Eur J Emerg Med* 2007; **14**: 230–2
47. Young O, Watters K, Sheahan P, Hughes J. Penetrating air gun wound in the neck. *Auris Nasus Larynx* 2008; **35**: 426–8
48. O'Connor J, Haan J. Spent bullet in the bronchus. *Am Surg* 2006; **72**: 345–6
49. Mandavia DP, Qualls S, Rokos I. Emergency airway management in penetrating neck injury. *Ann Emerg Med* 2000; **35**: 221–5
50. Tallon JM, Ahmed JM, Sealy B. Airway management in penetrating neck trauma at a Canadian tertiary trauma centre. *CJEM* 2007; **9**: 101–4
51. Weitzel N, Kendall J, Pons P. Blind nasotracheal intubation for patients with penetrating neck trauma. *J Trauma* 2004; **56**: 1097–101
52. Gallo AC, Adams BD. Emergency battlefield cricothyrotomy complicated by tube occlusion. *J Emerg Trauma Shock* 2009; **2**: 54–5
53. Sharma N, De M, Martin T, Pracy P. Laryngeal reconstruction following shrapnel injury in a British soldier: case report. *JLO* 2008; **123**: 253–6
54. Kotsev S. Airway management in a patient with a vascular injury and rapidly expanding neck haematoma. *Eur J Anaesthesiol* 2005; **22**: 556–8
55. Baron BJ. Penetrating and blunt neck trauma. In: Tintinalli JE, Kelen GD, Stapczynski JS, eds. 6th edition. *Emergency Medicine: a Comprehensive Study Guide*. New York: McGraw-Hill, 2004; 1590–5
56. Inaba K, Munera F, McKenney M, *et al*. Prospective evaluation of screening multislice helical computed tomographic angiography in the initial evaluation of penetrating neck injuries. *J Trauma Acute Care Surg* 2006; **61**: 144–9
57. Madnani DD, Steele NP, de Vries E. Factors that predict the need for intubation in patients with smoke inhalation injury. *Ear Nose Throat J* 2006; **85**: 278–80
58. Chow JL, Coady MA, Varner J, Cannon W, Spain D, Brock-Utne JG. Management of acute complete tracheal transection caused by nonpenetrating trauma: report of a case and review of the literature. *J Cardiothorac Vasc Anesth* 2004; **18**: 475–8
59. Atkins BZ, Abbate S, Fisher SR, *et al*. Current management of laryngotracheal trauma: case-report and literature review. *J Trauma Acute Care Surg* 2004; **56**: 185–90
60. Zatriqi V, Arifi H, Zatriqi S, Duci S, Rrecaj S, Martinaj M. Facial burns - our experience. *Materia Socio-Medica* 2013; **25**: 26–6
61. Graham CA, Ada HY, Chan SS, Rainer TH. Primary emergency surgical airway for trismus caused by electrical burn. *Burns* 2006; **32**: 1062–3
62. Huang C-C, Wu H-S, Lee Y-C. Extensive tracheobronchitis and lung perforation after alkaline caustic aspiration. *Ann Thorac Surg* 2010; **89**: 1670–3
63. Yeh CF, Lee TL. Critical airway induced by formalin injection: case report. *JLO* 2014; **128**: 107–9
64. Silberman M, Jeanmonod R. Aerodigestive tract burn from ingestion of microwaved food. *Case Rep Emerg Med* 2013; **2013**: Article ID 781809
65. Bittner EA, Shank E, Woodson L, Martyn JJ. Acute and perioperative care of the burn-injured patient. *Anesthesiology* 2015; **122**: 448–64
66. Miller K, Chang A. Acute inhalation injury. *Emerg Med Clin North Am* 2003; **21**: 533–57
67. Mutlu GM, Budinger GR. Incidence and outcomes of acute lung injury. *N Engl J Med* 2006; **354**: 416–7
68. Fraser DJF, Venkatesh B. Recent advances in the management of burns. *Australas Anaesth* 2005. Available at: http://www.anzca.edu.au/documents/05_fraser.pdf (accessed 24 June 2016)
69. Makino H, Igarashi H, Suzuki Y, *et al*. Combined usage of an Airway Scope and gum elastic bougie for emergency airway management in a patient with neck stab wound. *Eur J Anaesth* 2012; **29**: 238
70. Black JJM. Emergency use of the Airtraq laryngoscope in traumatic asphyxia: case report. *Emerg Med J* 2007; **24**: 509–10
71. Esnault P, Prunet B, Cotte J, *et al*. Tracheal intubation difficulties in the setting of face and neck burns: myth or reality? *Am J Emerg Med* 2014; **32**: 1174–8
72. Eastman AL, Arnoldo BA, Hunt JL, Purdue GF. Pre-burn center management of the burned airway: do we know enough? *J Burn Care Res* 2010; **31**: 701–5
73. Mackie DP, van Dehn F, Knape P, Breederveld RS, Boer C. Increase in early mechanical ventilation of burn patients: an effect of current emergency trauma management? *J Trauma Acute Care Surg* 2011; **70**: 611–5
74. Amani H, Lozano DD, Blome-Eberwein S. Brother, have you got a light? Assessing the need for intubation in patients sustaining burn injury secondary to home oxygen therapy. *J Burn Care Res* 2012; **33**: e280–5
75. Toon MH, Maybauer MO, Greenwood JE, Maybauer DM, Fraser JF. Management of acute smoke inhalation injury. *Crit Care Resusc* 2010; **12**: 267–7
76. Hampson NB, Piantadosi CA, Thom SR, *et al*. Practice recommendations in the diagnosis, management, and prevention of carbon monoxide poisoning. *Am J Respir Crit Care* 2012; **186**: 1095–101
77. Cummings TF. The treatment of cyanide poisoning. *Occ Med* 2004; **54**: 82–5
78. Keldahl M, Sen S, Gamelli RL. Gastric rupture after cardiopulmonary resuscitation in a burn patient. *J Burn Care Res* 2006; **27**: 757–9
79. Mlcak RP, Suman OE, Herndon DN. Respiratory management of inhalation injury. *Burns* 2007; **33**: 2–13
80. Siah S, Wali El A, Ababou K, Sabah TN, Drissi NK, Ihrai I. Intubation difficile chez le brule de la face et du cou a laphase de sequelles. *Ann Burns Fire Disasters* 2006; **19**: 74–7

81. Kerekhanjanarong V, Supiyaphun P, Saengpanich S. Upper aerodigestive tract burn: a case report of firework injury. *J Med Assoc Thai* 2001; **84**: 294–8
82. Valdez TA, Desai U, Ruhl CM, Nigri PT. Early laryngeal inhalation injury and its correlation with late sequelae. *Laryngoscope* 2006; **116**: 283–7
83. Levitan RM. NO DESAT! Nasal oxygen during efforts securing a tube. *Emergency Physicians Monthly* 2010. Available at: http://epmonthly.com/article/no-desat/ (accessed 24 June 2016)
84. Smith J, Russell R, Horne S. Critical decision-making and timelines in the emergency department. *J R Army Med Corps* 2011; **157**: S273–6
85. Hagberg A, Johnson S, Pillai D. Effective use of the esophageal tracheal Combitube following severe burn injury. *J Anesth* 2003; **15**: 463–3
86. Fleissig Y, Rushinek H, Regev E. Intermaxillary fixation screw for endotracheal tube fixation in the edentulous patient with facial burns. *Int J Oral Maxillofac Surg* 2014; **43**: 1257–8
87. Mittal G, Mittal RK, Katyal S, Uppal S, Mittal V. Airway management in maxillofacial trauma: do we really need tracheostomy/submental intubation. *J Clin Diagn Res* 2014; **8**: 77–9
88. Cook TM, Woodall N, Frerk C, on behalf of the Fourth National Audit Project. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. *Br J Anaesth* 2011; **106**: 617–31
89. Gleeson S, Groom P, Mercer S. Human factors in complex airway management. *BJA Education* 2016; **16**: 191–7
90. Arul GS, Pugh H, Mercer SJ, Midwinter MJ. Optimising communication in the damage control resuscitation–damage control surgery sequence in major trauma management. *J R Army Med Corps* 2012; **158**: 82–4
91. Mercer SJ, Tarmey NT, Mahoney PF. Military experience of human factors in airway complications. *Anaesthesia* 2013; **68**: 1080–1

Handling editor: T. Asai

3.3 A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma. Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P. *British Journal of Anaesthesia* 2016: 117 (S1): i49–i59

Page 11

At the time of writing, it was known that the management of non-iatrogenic trauma to the airway was rare (113) and it was proposed that exceptional human factors were required to manage patients with complex airway problems (96). The UK-Defence Medical Services were running workshops on the management of trauma to the airway on the Military Operational Surgical Training Course (94) to prepare Military Anaesthetists to deploy on operations. Mental models for the management of blunt and penetrating trauma were yet to be formally developed and was an area of practice that we wished to concentrate on during this project.

3.3.3 What the paper added or contributed to the 'global' clinical community?

This paper has been cited in the medical literature 14 times. I have used the basis of this publication to develop the following further publication.

- Human Factors in Preventing Complications in Anaesthesia. Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ. *Anaesthesia* 2018; **73(S1)**: 12-24

I am now regularly invited to review articles on the management of airway trauma by the *British Journal of Anaesthesia*. I have also been invited to speak at the Annual Congress of Japanese Society of Anaesthesiologists on this subject in June 2020. This project has been discussed during the following invited national presentations.

- **Simulation for Trauma Training.** Trauma Care Conference, Yarnfield Conference Centre, Stafford, 6 March 2019
- **Wrong Site Block,** Royal College of Anaesthetists Updates Meeting, Hilton Hotel, Liverpool, 26 November 2018
- **Improving Trauma Teams. Understanding Why Teams Don't Work,** Cambridge Trauma Conference, Churchill College Cambridge, 28 April 2018
- **Bombs, Bullets and Bicycles. Management of Airway Trauma,** Difficult Airway Society Annual Scientific Meeting**,** Mermaid Theatre, London, 24 November 2017
- **Human Factors in Complex Trauma,** Association of Anaesthetists of Great Britain and Ireland Annual Congress, BT Convention Centre, Liverpool, 28 September 2017

The articles listed in Table 3.1 have also cited this publication (I have only listed articles in English)

Table 3.1. Articles citing A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma. Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P. *British Journal of Anaesthesia* 2016: 117 (S1): i49–i59

Estime SR, Kuza CM. Trauma Airway Management. Induction Agents, Rapid Versus Slower Sequence Intubations, and Special Considerations. *Anesthesia Clinics* 2019; 37: 33-50	This article is an overview of the management of the airway in trauma and discusses the mental models developed in our publication.
Woolley T, Round JA, Ingram M. Global lessons: developing military trauma care and lessons for civilian practice. *British Journal of Anaesthesia* 2017; 119(S1): i135–i142.	I was asked by the *British Journal of Anaesthesia* to review this article and it gives an overview of military trauma care. The mental models and algorithms developed in our article are discussed.
Kovacs G, Sowers N. Airway Management in Trauma. *Emergency Medicine Clinics of North America* 2018; 36: 61–84	This article is an overview of the management of the airway in trauma and cites our systematic review in terms of the management models that we describe.
Gadd K. Airway management in suspected laryngotracheal trauma in an uncooperative patient. *Anaesthesia Cases.* 2017. http://dx.doi.org/10.21466/ac.AMISLTI.2017	This is a case review that cites our article to describe the different mechanisms of injury that have been quoted in the literature for airway trauma.
Yang X, Xu Z, Du J, et al. Penetrating injuries to the oropharyngeal cavity in children-a challenge to the anesthetist. *International Journal of Clinical and Experimental Medicine* 2018;11(4):4290-4294	The authors of this paper have cited our publication to comment on the physiological characteristics of the paediatric airway, which is an error as our article only deals with adult patients.
Kelbert EW. Assessment and initial management of laryngeal injuries. *Journal of the International Society of Head and Neck Trauma (ISHANT*) 2016:5	This is an overview of the management of laryngeal injuries. The authors cite our paper when discussing the use of a fiberoptic videolaryngoscope to pass through an endotracheal tube and into the trachea to avoid creating a false passage.
Milne B, Kandasamy G. Awake tracheal intubation for blunt airway trauma. *Anaesthesia Reports* 2019; 7: 39-42	This is a Case Report that quotes our systematic review and centres around the management of blunt trauma to the neck following a fall.

3.3.4 Where are we now?

The assimilation of the knowledge from the literature review, particularly from case reports and case series allowed us to construct several guidelines based on common themes. The three areas that we were particularly keen to highlight were that patients with trauma to the airway should maintain spontaneous ventilation if at all possible until induction of general anaesthesia, intubation should be under direct vision to avoid the creation of a false passage; and that both intermittent positive pressure ventilation and cricoid pressure during a rapid sequence induction should be avoided. This direction is at odds with the revised Difficult Airway Society Guidelines of 2015 for the unanticipated difficult airway (93). Trauma to the airway is firmly an 'anticipated difficult airway' and so must be treated differently.

Our systematic review concludes with shared mental model maps for burns and maxilliofacial trauma and for laryngotracheal, tracheal and bronchial trauma. These guidelines are important to ensure that the team leader (usually the senior anaesthetist) maintains situational awareness and can brief the trauma team prior to embarking on securing the patient's airway. I have recently been invited to write an editorial on the management of non-iatrogenic airway trauma for *Trauma (currently inpress)*.

3.3.5 Reflections on the methodology/method(s)

3.3.5.1 Literature Review

Embase, Medline, and Google Scholar were searched for papers published after the year 2000 reporting on the acute airway management of adult patients who had suffered airway trauma. The search included full-text reports of articles from peer-reviewed journals and conference abstracts published in English, and there were no restrictions to the studies reviewed. The reference lists of the articles reviewed were also scrutinized for additional

relevant articles and book chapters. The titles and abstracts of the references obtained were reviewed by two independent reviewers and inclusion criteria were papers reporting adults older than 18 years of age with airway trauma; papers published on or after 2000; and papers reporting airway trauma (blunt, burn, penetrating, blast, or miscellaneous injuries) and anaesthetic management. The full protocol and search strategy were registered with and published by PROSPERO (http://www.crd.york.ac.uk/ PROSPERO, ID: CRD42016032763) and available in Appendix 2. Again, by registering with a national organisation, we ensured that our methodology was peer-reviewed and transparent. The literature review summarises identified work around the management of blunt trauma, penetrating and blast injury and burns injury.

This systematic review used a more extensive literature review than the first paper discussed in the thesis and included Embase, Medline, and Google Scholar. Despite this there were 68 papers that were identified only when a further trawl of references in individual articles was made. This is an interesting observation as despite undertaking a literature review that was conducted by a University Librarian, with recognised and established medical databases (and also google scholar) a significant number of papers were initially missed. One explanation for this could be that the subject being investigated is quite ‘niche’ and not in the mainstream medical literature, this included single case reports of the management of particular injuries. I hope this will demonstrate that I am driving this unique area of medical practice into an arena that can be accessed by practicing anaesthetists in hospitals in the United Kingdom.

Section 4

Knowledge Translation

4.1 Introduction

I am a full-time clinician working in a busy major trauma centre in the North West of England and have previously served in the Royal Navy for over 20 years. My priorities are to improve the quality, standard and provision of care for patients involved in complex trauma. To facilitate this, it is key that new knowledge discovered from research and knowledge that is summarised from systematic reviews is disseminated to those working in the frontline. Although not part of this thesis, I am an established national speaker on the subjects of complex trauma, human factors and simulation in healthcare. I also have regular time in my job plan at Liverpool University Hospitals NHS Foundation Trust's High-Fidelity Simulation Centre where I undertake the training of the trauma team and introduce new concepts around the management of complex trauma. I consider myself to be a national expert on the application of human factors to the management of complex trauma.

Knowledge translation is defined as the exchange, synthesis and ethically sound application of knowledge to improve health and provide more effective health services (114). This definition fits with my aim as a senior leader in complex trauma services and an educator. In terms of trauma care, over the last five years, knowledge translation has been assembling the lessons learnt from recent conflicts in Iraq and Afghanistan (115) and reviewing other research from for example the Centre for Blast Injury based at Imperial College, London (https://www.imperial.ac.uk/blast-injury/) and disseminating to those working in the frontline in the major trauma centres. Barrett describes that by developing interactional expertise from the domain of study (in my case the management of the patient with complex trauma), the academic's primary goal is to develop a theoretical contribution through journal publication (116). It is appreciated that any research findings discovered can only then change population health outcomes if adopted and embedded by current healthcare systems, organizations and more importantly the frontline clinicians.

Kutner has suggested that it is important to explore the most effective ways of implementing existing evidence into practice as advances in research knowledge can take years to be implemented into, or actually change practice (117). A review of United Kingdom healthcare funding by Cooksey concluded that given the pace of innovation and research in the healthcare field, a 'knowledge gap' now exists and this has generated significant concern within healthcare research and policy (118). One famous example to demonstrate the existence of a knowledge gap, is that it took 200 years between the time that a clear and convincing cure for scurvy had been found until the findings were adopted by the Royal Navy and deployed sailors were given regular sources of Vitamin C. This example nicely highlights the difficulty of knowledge 'moving' from research into practice. It would appear that there are two separate groups; the research producers and potential research users, with the notion of a 'knowledge push' (from researchers to potential users) and 'knowledge pull' (from these users back to the researchers) (119). Research findings can only change population health outcomes if adopted and embedded by healthcare systems, organizations and clinicians (120).

The literature offers a variety of definitions, terminology and models relating to knowledge exchange. Pentland explains that in general, explanations of knowledge exchange propose an interactive and ongoing process of collaboration, which provides research users with information they perceive as relevant in easily usable formats whilst research producers receive information about the needs of users (121).

In 2008, Baumbusch suggests that knowledge translation has the potential to address the research-practice gap by bringing together researchers, who are typically academically based, and clinically based practitioners in a dynamic process (122). The World Health Organization has subsequently adapted the Canadian Institute of Health Research definition and defined knowledge translation as *'the synthesis, exchange, and application of knowledge by relevant stakeholders to accelerate the benefits of global and local innovation in strengthening health*

systems and improving people's health' (123). Mitton also describes knowledge exchange as an interactive interchange of knowledge between research users and researcher producers (124) which increases the likelihood that research evidence will be used in policy and practice decisions and to enable researchers to identify practice and policy-relevant research questions (125). Finally, Graham has written that knowledge translation is about turning knowledge into action and encompasses the processes of both knowledge creation and knowledge application (126). The context for knowledge transfer and exchange has been reported at two levels, local and the wider social, economic and cultural. Mitton identified that interactively engaging key leaders or champions is an important factor for successful Knowledge-Transfer and Exchange (127).

Six key components of knowledge transfer and exchange have been described (128). These consist of the knowledge transfer and exchange message, Stakeholders and process, inner context, social, cultural and economic context and evaluation. The Message reflects the information to be shared and should be 'needs driven' (128). It also must be credible, actionable and accessible and reflects the information to be shared. Within this component, the most common operational element was the idea that the '*message is needs-driven'*. This often-presented research as a clinical or practical problem. The Process component represents the activities intended to implement the transfer of knowledge (the 'push-pull' dynamic exchange of information) and includes the operational element of marketing (communicating) the message in a way that effectively 'pitched' to the target audience. The process itself is an interactive, targeted and skilled exchange of information. The Stakeholders represent the people involved on either side of the exchange process and has been described in terms of knowledge users (or knowledge consumers (129)) who are the clinicians at the front line, knowledge beneficiaries, who often represent the wider group of patients and families who benefit from the implementation and multiple stakeholders (130). The message itself is influenced by the Stakeholders and based on the message and the stakeholders the

knowledge producer should identify the processes to be used to ensure the message can be delivered to the stakeholders effectively (128).

This section of the thesis will describe the knowledge translation from Sections 2 and 3 and demonstrate how Human Factors have been introduced into various Military and Civilian Trauma Teams and their importance in the management of a patient involved in Complex Trauma. Only five articles will be presented for the purposes of this thesis, although a number of others will be quoted, and a list of my other publications are described in Appendix 1.

The first of the five papers is Human Factors in Trauma. Mercer SJ, Tarmey N, Park C *BJA Education* 2015; **15**: 231-236. This outlines where human factors fit into a trauma call in a civilian setting in the Emergency Department.

The second paper entitled Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma. Mercer SJ, Arul S, Pugh H, Midwinter MJ *Journal of the Royal Army Medical Corps* 2014; **160**: 105-108 outlines the importance of human factors in a trauma call in the UK-Defence Medical Services.

The third article, Human Factors in Complex Airway Gleeson S, Groom P, Mercer SJ**.** *British Journal of Anaesthesia Education* 2016; **16**: 191-197 expands on the knowledge of the airway article in original research and the systematic review and discusses the importance of human factors in the management of the anticipated difficult airway with practical applications.

Current activity in the UK-Defence Medical Services focuses around Contingency Operations (these will be defined later in the thesis). The fourth paper, Human Factors on Contingency Operations. Mercer SJ, Khan M, Scott T, Matthews J, Henning D, Stapley S. *Journal of the*

Royal Army Medical Corps 2017: **163**; 78-83 is a discussion paper on the importance of Human Factors as part of contingency operations.

One of the most neglected Human Factors is that of Followership. The final paper in this section, Followership in Complex Trauma. Fadden S, Mercer SJ. *Journal of Trauma* 2019; **21**: 6-13, highlights the importance of followership in complex trauma.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

3. Title of Research Output

Human Factors in Trauma Mercer SJ, Tarmey N, Park C BJA Education 2015; 15: 231-236

4. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (60%) - inital idea for publication, 1st draft and subsequent drafts
N Tarmey (20%), case description and subsequent drafts, C Park (20%), case description and subsequent drafts

5. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
N Tarmey		nicktarmey@gmail.com
C Park		clairepark1@nhs.net

6. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature: _____ Date: _____

(Director of Studies/Advisor)

7. Signature of Faculty Research Degrees Administrator

Signature: _____ Date: _____

(Faculty Research Degrees Administrator)

Human factors in complex trauma

S Mercer MBChB MAcadMEd FHEA FCoIIT FRCA MMEd
C Park MBE FRCA FFICM DipIMC DipRTM RAMC
NT Tarmey FRCA DICM DipIMC RCS(Ed) RAMC

Revalidation FOR ANAESTHETISTS
RCA Revalidation matrix
Matrix reference
1102, 1103
2A02, 2A05, 3A10

Key points

Exemplary human factors are vital to the timely assessment and treatment of a complex trauma patient.

The designation of a trauma team leader allows a 'hands off' coordination of trauma team activity and maintenance of situational awareness.

Maintaining situational awareness allows an early reaction to changing physiology.

Communication is vital and can be facilitated by regular updates or 'sit reps'.

Followership is essential to the functioning of the complex trauma team.

S Mercer MBChB MAcadMEd FHEA FCoIIT FRCA MMEd
Royal Navy Consultant Anaesthetist
Anaesthetic Department
Aintree University Hospital
Liverpool L9 7AL
UK
Tel: +44 7970153168
E-mail: simonjmercer@hotmail.com
(for correspondence)

C Park MBE FRCA FFICM DipIMC DipRTM RAMC
Consultant in Anaesthesia, Intensive Care and Pre-Hospital Care
Kings College Hospital and London's Air Ambulance
London
UK

NT Tarmey FRCA DICM DipIMC RCS(Ed) RAMC
Consultant in Critical Care and Anaesthetics
Queen Alexandra Hospital Portsmouth
Portsmouth
UK

Human factors are now integrated into everyday anaesthetic practice, as a result of the work performed over a decade ago looking at anaesthetists non-technical skills (ANTS).[1] Much of this work was performed after key publications in the USA[2] and the UK[3] highlighting that human error and system design was responsible for patient harm. Subsequent high profile cases relevant to anaesthesia[4,5] have brought to light where human factors failures have led to patient death. In 2010, the Royal College of Anaesthetists dedicated the entire Anniversary Meeting to Human Factors and published a supplement to the *British Journal of Anaesthesia*. Some of the human factors related to the trauma team are listed in Table 1.

The 2007 report 'Trauma: Who Cares?'[6] highlighted the deficiencies in the delivery of trauma care in the UK, some of which resulted from failures in decision-making, communication, and team-work. Following on from this report, there has been the development of trauma centre networks around the country and a perceived improvement in trauma care delivery. The UK Defence Medical Services (UK-DMS) have attributed much of the success of their trauma care in Afghanistan to exemplary human factors,[7] particularly in the organization, briefing, and co-ordination of the trauma team.[8] This article will focus on a typical complex civilian trauma case (described in Box 1) arriving in a UK Major Trauma Centre and will demonstrate how lessons learnt by the UK-DMS are now being translated into civilian practice.

Preparing the team

Usually, there is a prehospital alert from the trauma scene and the trauma team is activated ~10 min before the estimated time of arrival. The composition of a typical UK civilian trauma team is listed in Table 2. Many NHS trauma teams are now led by a consultant (usually Emergency Physician) and will have activation criteria to ensure that the team is only mobilized when required. This is based on the mechanism of injury, anatomy, and physiology. Typical activation criteria are listed in Table 3.

By ensuring that the trauma team arrives before the patient, the trauma team leader (TTL) is given the opportunity to brief the team. This allows a projection of mental models of what the likely clinical sequence is going to be, promoting good followership. During the preparation phase, there is the opportunity to check equipment and draw up expected drugs. The anaesthesia team often has a 'wet pack' of intubation drugs,

Box 1 Clinical case

Injury at 20:10

A 25-yr-old male was cycling home in central London when he was hit by and dragged under the wheels of an articulated lorry as it was turning left. He had been cycling along on the inside of the lorry, and had gone underneath the rear axle as it turned.

He was managed on scene by two London Ambulance Service Paramedic Crews, and an ex-Helicopter Emergency Medical Service (HEMS) team paramedic. HEMS were requested but were on another mission.

The patient was not trapped, and so was pulled out from under the lorry, with 'manual in-line stabilization' *in situ* and then a cervical-spine collar, orthopaedic scoop stretcher, and pelvic binder were applied. Oxygen was administered via a 15 litre 'non-rebreather' face mask and i.v. access was obtained with 16 G cannula in the left ante-cubital fossa. One gram of tranexamic acid was given. The patient was agitated and in pain and was given 10 mg morphine i.v., before being transported to the nearest major trauma centre.

doi:10.1093/bjaceaccp/mku043
Continuing Education in Anaesthesia, Critical Care & Pain | 2014

analgesia, antibiotics, and key trauma drugs such as tranexamic acid. Contingency plans are discussed (such as dealing with a difficult airway) and telephone alerts are made to the operating theatre (OT), radiology, and transfusion.

On arrival at hospital, it is important that the handover is conducted in silence. Unless there is an impending airway problem or visible catastrophic haemorrhage then the patient should not be touched until the handover is completed. This ensures that everyone in the trauma team is aware of the handover and can start the resuscitation 'on the same page'. The UK-DMS use the acronym 'AT-MIST', standing for Age, Time of injury, Mechanism of injury, Injuries sustained, and Treatment given. This is described in Box 2 for the example patient.

Table 1 Typical human factors relevant to the trauma team

Human factor	Example
Leadership	In the trauma theatre, the anaesthetist is handed over the role of leader from the TTL. In complex trauma, there are often several surgical teams working at once and so this requires co-ordination particularly in the timings of tourniquet release
Situational awareness	The TTL should be 'hands off' as this allows them to maintain an 'all round look' (some people ask 'who is driving the bus?'). Initial information will come from the patient's handover from the paramedics, primary survey, monitoring, and initial tests such as venous blood gas
Team-working	The trauma team is a large, resource-rich unit and it is important that activity is coordinated with members performing as a team and not as individuals
Followership	Other members of the trauma team are 'followers' and must anticipate changing situations in the trauma bay. This might include preparing equipment, making phone calls to order tests or making suggestions to the team leader
Communication	There is the potential in a serious trauma for the noise levels to be raised. The TTL must ensure that noise is kept to a minimum to avoid communication failures. It is also important that observations and administered drugs are verbalized so that the team leader and scribe are aware

Table 2 Composition of a typical trauma team in an NHS major Trauma centre. ED, emergency department; ST, speciality trainee; HCA, healthcare assistant

- Trauma team leader (ED consultant)
- Primary survey doctor (ED SpR)
- Anaesthetist 1 (ST4–7)
- ODP
- Scribe (trauma nurse coordinator)
- ED nurse 1 (circulator)
- ED nurse 2 (rapid infuser)
- ED nurse 3 (rapid infuser)
- Runner (HCA)
- Orthopaedic surgeon (ST4–7)
- General surgeon (ST4–7)
- Radiographer

Table 3 Trauma team activation criteria (taken from Kings College Hospital, Major Trauma Service: Information for Members of the Trauma Team). This will apply to patients arriving at the hospital or who have a prehospital alert

1. Traumatic event and one of the following:
   - Oxygen saturation <90%
   - Systolic arterial pressure <90 mm Hg
   - Respiratory rate <9 or >29 bpm
   - GCS <14
2. Penetrating injury to
   - Head
   - Neck
   - Chest
   - Abdomen
   - Pelvis
   - All gunshot wounds
3. Fractures
   - Open or depressed skull fractures
   - Pelvic fracture
   - Two or more proximal long bone fractures
   - Flail chest
4. Traumatic amputation
5. Blast or crush injury
6. Major burns
   - 10% total body surface area but lower threshold in child or elderly
   - Combination of burns and trauma
7. Road traffic crash
   - High speed crash (>30 mph) or pedestrian *vs* vehicle at >20 mph
   - Separation of rider and bike
   - Intrusion into passenger compartment
   - Ejection from vehicle
   - Death in the same passenger compartment
   - Bull's eyed windscreen
   - 20 min extrication time
8. Falls
   - Height of >3 m
   - Paediatrics—consider the age and height of the child in relation to the height fallen
9. HEMS transfer
10. Drowning/submersion

Box 2 Handover: AT-MIST on arrival at 21:00

A 25 yr
T 20:10
M Cyclist *vs* lorry
I R-sided chest injury, abdominal distension and tenderness, and probable pelvic fracture
S Sp_{O_2} 89%, airway patient, respiratory rate 35, heart rate 130, no radial pulse present, agitated, GCS 13, moving all four limbs, in pain.
T 15 litre O_2, c-spine collar, orthopaedic scoop stretcher, pelvic binder, 16 G i.v. access in left ante-cubital fossa, 1 g tranexamic acid, 10 mg morphine i.v.

Box 3 Management in the ED. *Ketamine used as an induction agent has gained popularity for haemodynamically compromised patients. It allows a more cardiovascularly stable anaesthetic when compared with other drugs such as propofol or thiopental

- 2 units of red blood cells (RBC) given immediately via i.v. in ACF
- RSI with 1 mg kg^{-1} ketamine*, 1 μg kg^{-1} fentanyl, and 1 mg kg^{-1} rocuronium
- Immediate bilateral thoracostomies (large amount of air and some blood release on right). Intercostal chest drains sited
- Subclavian central venous line (8.5 Fr) sited on right
- RBC switched to central line, and 2 further units given
- Code Red pack A arrived from transfusion and fresh-frozen plasma started
- Second tranexamic acid dose of 1 g started as infusion
- CT scan urgently requested and transferred with Belmont Rapid Infuser (Belmont Instrument Corporation, Boston, MA, USA) running throughout.

Management in the emergency department

The initial management in the emergency department (ED) is described in Box 3.

Situational awareness and the trauma team

The complex trauma patient described in Box 1 requires a full trauma team response and the potential for the clinical condition to worsen demands exceptional situational awareness. Having a designated senior TTL allows one person, who should remain 'hands-off' the patient, to retain an overall situational awareness. One commonly accepted definition of situational awareness is 'the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future',[9] and this accurately describes how the TTL should be thinking throughout the assessment in the trauma bay. Although the TTL has overall responsibility for the team response, the anaesthetist also has an important responsibility. They must advise the TTL, provide relevant information at an appropriate time for it to be received, and assist with the decision-making process.

Damage control resuscitation

The concept of damage control resuscitation includes haemostatic resuscitation and identification of injuries and therefore the source of bleeding to achieve haemorrhage control.[10] Resuscitation to normotension is necessary after haemorrhage control in order to achieve adequate peripheral tissue perfusion. This process requires the activation of a massive transfusion protocol and communication with the transfusion laboratory. In many trauma centres, the term 'Code Red' is used to indicate a patient with major haemorrhage who requires the massive transfusion protocol to be activated. Code Red activation criteria include a systolic arterial pressure $<$90 mm Hg (at any time), patients who are non-responders to fluid boluses and suspected or confirmed haemorrhage. All EDs should have at least 2 units of red blood cells (RBC) available, but the initial massive haemorrhage protocol should also initiate 'shock packs' including clotting products. These may vary in different hospitals but are likely to contain products as in packs A and B described in Table 4. Where a HEMS team is in attendance on scene, they will declare a 'Code Red' as soon as possible to the receiving ED, and may also give prehospital red cell transfusion.

Table 4 An example of Code Red 'shock pack' contents

Pack A	Pack B
4 RBC	6 RBC
4 FFP	4 FFP
	Cryopreciptate, 1 adult therapeutic dose (2 pools of 5 units)
	Platelets, 1 adult therapeutic dose

The optimal ratio of blood product transfusion in traumatic haemorrhage is still being investigated, but the current UK-DMS massive haemorrhage protocols have been summarized recently.[11] The main aim should be to achieve identification of bleeding points and therefore source control as quickly as possible while replacing the products that are being lost. It is vital that the decision-making process around bleeding control is made swiftly and has senior input to ensure that there are no prolonged delays in treatment.

The trauma team anaesthetist

The trauma team anaesthetist must make their own assessment of the patient's physiology and injuries in order to decide on the most appropriate time to perform a rapid sequence induction (RSI) of anaesthesia and also to guide the haemostatic resuscitation. Deciding whether to go to the CT scanner, the angiography suite or the OTs next will be part of this decision-making process. This requires the anaesthetist to have good situational awareness regarding the state of the patient's physiology and the injuries that are being identified. As the trauma anaesthetist, there are a number of pitfalls that can occur

due to poor human factors in the ED phase. These are summarized in Table 5.

The patient described in Box 1 has increased respiratory effort, low oxygen saturations, and a pneumothorax on the right. He requires intubation immediately to improve oxygen delivery and to reduce the work of breathing. The patient's response to blood products must be closely observed in order to guide therapy and identify whether he is responding to the resuscitation or is still actively bleeding. The primary survey is conducted simultaneously and is coordinated by the TTL.[8] Concurrent activity is required, ideally with one anaesthetist inserting large-bore central access such as an 8.5 Fr 'trauma line' into the subclavian vein in order to rapidly infuse the blood products, while the other anaesthetist prepares to perform the RSI.

In the ideally staffed trauma team, there should be two anaesthetists for 'Code Red' patients such as this to enable one to focus on central access and blood product replacement, while the other manages the airway and ventilation. However, this is often not possible, even in many major trauma centres. As the sole trauma anaesthetist, it is easy for your 'bandwidth' (i.e. your available mental capacity) to become overloaded by a very sick patient requiring immediate multiple interventions. Recognition of this possibility and effective utilization of other team members is essential during the RSI.

Trauma patients requiring emergency intubation with simultaneous resuscitation have 'a lot going on' around them to cause distraction during the RSI. The option to wake if intubation fails, as described in the Difficult Airway Society Guidelines,[12] is not appropriate when they require ongoing resuscitation and immediate surgical intervention. Based on collective experience and published literature,[13] the UK-DMS have taken a default position of securing the airway in the majority of trauma patients requiring RSI with a Macintosh size 4 laryngoscope blade and a gum-elastic bougie with two suction devices close to hand. No more than three attempts at intubation (with re-oxygenation in between attempts) are permitted before clear communication of failed intubation with immediate progression to a surgical airway. RSI in trauma will usually require manual in-line stabilization and must be performed in a 'sterile cockpit', that is, there should be silence during the RSI to allow full concentration and identification and communication of problems.[12] The anaesthetist must allocate roles to the team as listed in Table 6, while the TTL provides situational awareness to avoid fixation errors.

Table 5 Pitfalls for the trauma anaesthetist in ED. TTL, trauma team leader; E'_{CO_2}, end-tidal carbon dioxide measurement (measured by caponography)

Pitfall	Measures to mitigate risk
Not hearing handover	Do not transfer ventilator or check tracheal tube during the prehospital handover: do it before or afterwards
Not anticipating injuries sustained	Understand the mechanism of injury and therefore potential injuries sustained
Lack of situational awareness	Understand the physiology of the patient, especially respiratory and cardiovascular status, and listen to the TTL's plans. Be aware that when your 'bandwidth' is overloaded you may not hear everything
Poor followership	Ensure that information is delivered to the TTL when they are 'ready to receive' it. Important information will not be heard or interpreted if delivered in the wrong way at the wrong time
Confusion over roles during RSI	Clearly allocate roles during preparation for RSI
Omission of important equipment during RSI (e.g. E'_{CO_2})	Use a checklist, especially if assistant is not regularly assisting at intubations
Lack of situational awareness during RSI	Use assistant and TTL as your eyes and ears during intubation. This prevents task fixation
Attempted insertion of an arterial line when the arterial pressure is very low	This does not improve the arterial pressure, it just delays surgical intervention and causes loss of situational awareness. The arterial line can be sited once the patient is on the operating table

Table 6 Team roles for RSI

Manual in-line stabilization
Cricoid pressure/laryngeal manipulation
Drug administration
Intubation

Table 7 The command huddle for critical decision-making in ED. IR, interventional radiology

Key people

ED TTL

- Provides overall leadership and situational awareness, including an understanding of the resources available

Lead surgeons (ideally general surgery and orthopaedics)

- Provide expert assessment of the injuries found, surgical options available, and priorities for surgical treatment

Lead anaesthetist

- Provides expert assessment of physiological stability, response to transfusion, and priorities for airway management

Key decisions

Treat here or transfer to another hospital?

- Does our hospital have the resources and expertise to manage this case safely?
- What are the relative risks of transferring to a specialist centre *vs* treating here?

RSI in ED or in the OT?

- How great is the risk of airway obstruction or respiratory failure before reaching the OT?
- How much safer is it to anaesthetize this patient in the OT *vs* ED?
- Will this patient be able to tolerate the move to CT/OT without anaesthesia?

CT first or straight to OT or IR?

- How much delay will be caused by getting a CT before surgery?
- Is the patient stable enough to tolerate this delay?
- How likely is it that the CT results will alter this surgery?

If straight to OT, which body cavity should be opened first?

- Where does the most time-critical injury seem to be?
- Is it possible to get proximal control of any bleeding?

If pelvic or stab wound arterial bleeding is IR more appropriate than OT?

- Is it arterial bleeding that is not likely to respond to packing?
- Is there concurrent intra-abdominal bleeding requiring laparotomy?

IR, interventional radiology.

Box 4 CT scanner information

Injuries identified on CT

- Bilateral rib fractures
- Flail chest posteriorly on right (ribs 2–8)
- Single rib fractures posteriorly on left (ribs 3–7)
- Grade 5 liver laceration, actively extravasating
- Unstable open pelvic fracture, actively extravasating

Box 5 Summary of treatment up to arrival at the OT (21:30)

Total transfusion 8 RBC and 4 FFP (with next 4 FFP *en route* to the OT from blood bank)

Anaesthesia maintained with 1% propofol infusion at 8 ml h^{-1} and midazolam boluses

AP 90/60 but only maintained while actively infusing blood products

HR 120

Weakly palpable radial pulses

Box 6 Summary of treatment up to handover in the critical care unit

OT interventions

Trauma laparotomy and packing to the liver

Retroperitoneal packing

External fixation of the pelvis

Ongoing blood product requirements despite the above procedures so progression to interventional radiology for embolization of a branch of the right internal iliac artery.

Transfer to critical care

Decision-making

The time spent in ED is important, but it is only a step towards more definitive investigations and treatment. A successful ED phase will result in the patient exiting the department quickly, with a tolerable degree of physiological stability, for timely and appropriate investigations and/or surgery.

The end of the ED phase is a time when critical decisions about further investigations, treatment, and transfer must be made. These decisions need a combined approach from at least three senior members of the team: the TTL; the lead surgeon(s); and the lead anaesthetist. In the UK-DMS, this short meeting is known as the 'Command Huddle'.[14] Key decisions that must be made at this stage are shown in Table 7. For timely and effective decisions to be made, these people must be present in person and must have sufficient seniority to make difficult decisions. Attempting to make do with junior staff in ED and telephone communication with remote consultants can only increase the risk of delayed and inappropriate care.

The patient described in Box 1 is transferred to the CT scanner and the information obtained is shown in Box 4. He is immediately transferred to the OT with a summary of treatment described in Box 5 and further interventions in Box 6.

Team working

On transfer from ED to the OT, team leadership for the resuscitation will move from the ED TTL to the lead anaesthetist. This transition of responsibility comes at a busy time for the anaesthetist and must be managed carefully to avoid errors. The safest solution is probably for the ED TTL to stay with the team and in control until the patient is safely positioned and established on the ventilator in the OT.

On arrival in the OT, it is important to ensure that the whole team are aware of the clinical situation and surgical plans. This concise update, which can be combined with the WHO Checklist, is known

Table 8 Human factors pitfalls during trauma surgery

Pitfall	Measures to mitigate risk
Unnecessary conflict over basic principles and processes (e.g. refusal of blood bank to issue sufficient quantities of blood and clotting products)	Establish clear guidelines and standard operating procedures, supported by training and multi-speciality involvement
Lack of clear leadership (e.g. three anaesthetists working together, but no defined leader with overall situational awareness)	State clearly the name of the lead anaesthetist to the whole OT team. When other anaesthetists come to help, establish defined roles for each anaesthetist
Becoming task-focused (e.g. an anaesthetist becoming fixated on inserting an arterial line or a surgeon becoming fixated on one small aspect of the surgery)	Maintain 'hands-off' leadership of the anaesthetic when sufficient assistance is available. Delegate technical tasks to other team members
Not communicating effectively (e.g. an anaesthetist and surgeon both aware of their own problems but not of each other's)	Ensure whole team is aware and prepared for critical moments including: • clamps or tourniquets going on or off • packing or mobilizing large structures (e.g. liver, lung, or heart) Use brief, regular, structured, situational reports ('sit-reps')[14] to update the team, including: • Time spent in OT • Clotting and transfusion totals • Physiological status (including temperature and acidosis) • Surgical findings, progress, and future intent

by the UK-DMS as the 'Snap Brief'.[14] The key points of information that must be communicated include:

- the main injuries found on CT and clinical examination;
- the physiological status and degree of stability;
- the transfusion given up to this point, ongoing requirements, and degree of coagulopathy (including results of near-patient testing such as RoTEM®);
- the surgical plans and expected timescale of the operation.

During trauma surgery, there are a number of human factors-related pitfalls that must be avoided. A summary of the key risks and measures that may be taken to mitigate them is shown in Table 8.

The transition to postoperative critical care is unique in the process so far, in that there is usually enough time for proper planning and handover. The opportunity should be taken to engage with the intensive care unit at the earliest opportunity. This ensures that appropriate resources can be made available and will allow a thorough handover to the receiving clinicians (ideally in the OT) for seamless continued care.

Summary

The establishment of major trauma centres around the UK has led to the concentration of trauma experience in key hospitals. Human factors such as communication, situational awareness, team working, and decision-making are all key to the timely assessment and treatment of a complex trauma patient. This article describes some of the key human factors required by the trauma team with notorious pitfalls and strategies to avoid them.

Declaration of interest

None declared.

References

1. Fletcher G, McGeorge P, Flin RH *et al.* The role of non-technical skills in anaesthesia: a review of current literature. *Br J Anaesth* 2002; **88**: 418–29
2. Kohn LT, Corrigan JM, Donaldson MS, eds. *To Err Is Human: Building a Safer Health System*. Washington: National Academies Press, 2000
3. Department of Health. An Organisation with a Memory. London: The Stationery Office, 2000: VII–XI
4. The case of Elaine Bromiley. Available from http://www.chfg.org/resources/07_qrt04/Anonymous_Report_Verdict_ and_Corrected_Timeline_Oct_07.pdf (accessed 17 January 2014)
5. Sheriffdom of Glasgow and Strathkelvin under the Fatal Accidents and Sudden Deaths (Scotland) ACT 1976. Determination of Sheriff Linda Margaret Ruxton in Fatal Accident Inquiry into the death of Gordon Ewing. Available from http://www.scotcourts.gov.uk/ opinions/2010FA115.html (accessed 17 January 2014)
6. National Confidential Enquiry into Patient Outcome and Death. Trauma: Who Cares? London: NCEPOD, 2007
7. Midwinter MJ, Mercer S, Lambert AW *et al.* Making difficult decisions in major military trauma: a crew resource management perspective. *J R Army Med Corps* 2011; **157**: S299–304
8. Smith J, Russell R, Horne S. Critical decision-making and timelines in the emergency department. *J R Army Med Corps* 2011; **157**: 273
9. Endsley MR. Toward a theory of situation awareness in dynamic systems. *Hum Fact* 1995; **37**: 32–64
10. Jansen JO, Thomas R, Loudon MA *et al.* Damage control resuscitation for patients with major trauma. *Br Med J* 2009; **338**: 1778
11. Mercer SJ, Tarmey NT, Woolley T *et al.* Haemorrhage and coagulopathy in the defence medical services. *Anaesthesia* 2012; **68**: 49–60
12. Mercer SJ, Tarmey NT, Mahoney PF. Military experience of human factors in airway complications. *Anaesthesia* 2013; **68**: 1080–1
13. Mercer S, Lewis S, Wilson S *et al.* Creating airway management guidelines for casualties with penetrating airway injuries. *JR Army Med Corps* 2010; **156**: S355–60
14. Arul GS, Pugh H, Mercer SJ *et al.* Optimising communication in the damage control resuscitation-damage control surgery sequence in major trauma management. *J R Army Med Corps* 2012; **158**: 82–4

4.2 Human Factors in Trauma. MERCER SJ, Tarmey N, Park C *BJA Education* 2015; 15: 231-236.

4.2.1 Why this paper was written?

This article was an invited publication by the Editor of the *BJA Education Journal* and is one of the first published accounts of how human factors theory, particularly in non-technical skills and the lessons learnt from conflicts in Iraq and Afghanistan translate into practice in the National Health Service. In 2012 there was a reorganisation of trauma services in England which lead to the creation of major trauma centres (MTC) that were supported by trauma units in a regional network (56). A recent national review of data from the National Trauma Audit Research Network (TARN) published a paper that concluded that a change in the organisation of care for patients with severe injuries, including the development of Major Trauma Networks that cover the entire national population, was associated with a significant 19% (95% CI 3%–36%) increase in the odds of survival for trauma victims who reach the hospital alive (p=0.012) (2) (Figures 1.6 and 1.7). Although there is no strong evidence as yet, it seems sensible to postulate that the reorganization of services and an increased flow of patients with complex injuries to the Major Trauma Centres has allowed expertise and the trauma team as a whole to develop. I have observed this at Liverpool University Hospitals NHS Foundation Trust where I work. A knowledge transfer paper was required to inform those working in the frontline in Major Trauma Centres in England of the importance of Human Factors in complex trauma and to offer suggestions to improve practice.

4.2.2 What was known at the time of writing?

The aim of this article was to describe a typical trauma call involving a patient with complex trauma presenting to a Major Trauma Centre. Although the technical and clinical aspects of the case are very important, we have highlighted many of the human factors already discussed in the first three sections of the thesis and the use of an actual case has allowed individual aspects of human factors theory and their importance to be demonstrated. Examples of these

are described below in Table 3.2. This article also allowed the opportunity to highlight certain pitfalls that arise from poor human factors. These include

- Not hearing the handover
- Not anticipating the injuries sustained
- A lack of situational awareness
- Poor followership
- Confusion over roles during a rapid sequence induction of anaesthesia
- Omission of important equipment during rapid sequence induction of anaesthesia (e.g. end tidal CO2 monitoring)
- A lack of situational awareness during rapid sequence induction of anaesthesia
- Attempted insertion of an arterial line when the arterial pressure is very low

Table 3.2 Specific Examples of Human Factors in Trauma Calls

Preparation to receive a patient	There is a specific activation criterion so that members of the team are only activated when they are actually required to be present. This may promote the prevention of 'trauma fatigue'[1] Once arrived, the personnel involved will undertake introductions, including their name and role, and their clinical competencies. This is thought to encourage good followership. The team leader will give a brief to the team on what is expected. They may at this time impart their clinical mental model and ensure that others understand it. There is an opportunity here also for contingency planning and discussion of specialised roles such as surgical airway or chest drain insertion. There needs to be communication with the wider hospital at this point, particularly if a serious casualty is expected. This will include discussion with the operating theatre to ensure that there is a theatre staffed and ready with the correct equipment, the blood bank and also radiology to ensure the CT scanner available. Specific equipment is prepared, such as the Belmont Rapid Infuser.
Special Circumstances	**Code Red** – This is often declared by the pre-hospital team and criteria include systolic blood pressure of <90mmHg, active bleeding or where the patient is not responding to fluid boluses and suspected or confirmed haemorrhage (131). Activation of a Code Red will ensure a shock pack (4 units of packed red blood cells and 4 units of fresh frozen plasma) are ready on arrival of the patient and that senior clinicians attend the trauma call.

[1] The term 'trauma fatigue' has been mentioned at a few national conferences recently. There is no reference in the literature, but it refers to members of the trauma team becoming 'disengaged' from attending multiple trauma calls where their input was not required. These trauma calls will have arisen where the activation criterion was not followed correctly.

	Code Black – This is where the casualty moves directly with pre-hospital team to CT scanner prior to arrival in the trauma bay and then hands over the patient. MTCs that use a Code Black aim to obtain the CT scan results quicker and thus aid rapid decision making.
The Handover	It is crucial that all team members are aware of the initial information, particularly the mechanism of injury. One member of the team will check for a central pulse, patent airway and control of external catastrophic haemorrhage and then signal to the pre-hospital team member to conduct the handover. The pneumonic AT-MIST (*Age, Time of injury, Injuries Sustained, Signs and Symptoms and Treatment Given*) and if conducted in the same format every time then team members can listen process the information, they require This is conducted in silence and ensures that all team members are now on 'the same page'.
The Primary Survey	This is like a formula 1 pit stop (Figure 3.1 and Figure 3.2). The UK-DMS changed the way that the primary survey was conducted so that it follows a <c>ABC (132) format in complex trauma (catastrophic haemorrhage control first). The following roles are undertaken in a horizontal fashion(133) • Checking of tourniquets and pelvic binder positioning if applied • Administration oxygen (15 L via non-rebreather mask) • Cervical spine mobilisation In order to facilitate the passage of information and the maintenance of situational awareness, The Trauma Team Leader maintains a hands-off role (Figure 3.2). The team feeds in information and the TTL has a role similar to the conductor of an orchestra (134)
The Secondary Survey	This allows further information to be appreciated to aid the decision-making process and continues to be in a horizontal manner. The following roles are undertaken • Additional IV access inserted • Blood samples taken for full blood count, thromboelastometry, venous blood gas, group and save • Focused assessment with sonography for trauma scan (FAST) • Chest and pelvis X-rays • Commencement of haemostatic resuscitation if appropriate via a rapid infuser (Belmont) • Rapid sequence induction may be required.
Timings of interventions	Certain key procedures may need to be considered The need for a Rapid sequence Induction of Anaesthesia (RSI) • If an RSI is to occur, then roles must be allocated • There is a checklist for RSI outside the operating theatre environment • A 'silent cockpit' is assumed

- Does the patient require a whole body CT or transfer to the operating theatre or Interventional Radiology or Critical Care. A typical patient pathway is shown in Figures 1.9 and 1.10.

4.2.3 What the paper added or contributed to the 'global' clinical community?

This article provides a summary of the importance of human factors in managing complex trauma in a civilian setting at a major trauma centre. It has been cited 14 times although only 4 by articles that I have not been involved with. A low citation rate may be expected, given the paper's readership is those clinicians and the wider multi-disciplinary team involved in trauma who may not regularly publish. The *BJA Education Journal* is peer reviewed and is published monthly along with the *British Journal of Anaesthesia* and is delivered to all anaesthetists who are registered with the Royal College of Anaesthetists. My intention was to write an article to publicise the importance of human factors in complex trauma and I considered this journal to be the best vehicle to achieve this. I am not surprised that the article has not been cited many times as the readership are predominantly not academics but 'frontline' trauma anaesthetists. A limitation to this paper is that it has been written based on expert opinion only, with all three authors being very experienced trauma anaesthetists working in both the UK-Defence Medical Services and busy Major Trauma Centres in England. This could potentially be a source of bias.

The following concepts are introduced and discussed in terms of the 'civilian major trauma centre'.

Command Huddle

The Command Huddle is a particularly important part of the trauma call and was first described in a discussion paper on improving the communication during trauma calls (14). The following key individuals are present.

<u>The Trauma Team Leader</u>

- Role is to provides overall leadership and situational awareness, including an understanding of the resources available

Lead surgeons (ideally general surgery and orthopaedics)

- To provide expert assessment of the injuries found, surgical options available, and priorities for surgical treatment

Lead anaesthetist

- Provides expert assessment of physiological stability, response to transfusion, and priorities for airway management

4.2.4 Where are we now?

This article allowed key decisions to be highlighted and the need for good human factors when making them; and the following key decisions are discussed. This provides individuals with the opportunity to develop their own mental models in the context of their own mature system. The following 4 decisions are discussed

4.2.4.1 Decision 1. Treat here or transfer to another hospital?

To make this decision, it must be clear as to whether the receiving hospital has the resources and expertise to manage this case safely. If it does not, then an early transfer to a sub-speciality hospital might be required. The relative risks of transferring to a specialist centre versus treating in situ must also be considered.

4.2.4.2 Decision 2. RSI in in the Emergency Department or in the Operating Theatre?

A rapid risk assessment must be made as to how great the risk of airway obstruction or respiratory failure is before reaching the operating theatre (OT). Additional questions that add to this decision will be how much safer is it to anaesthetize this patient in the OT vs ED? Will this patient be able to tolerate the move to CT/OT without anaesthesia? Should a rapid sequence induction be required, this would ideally occur in silence similar to a 'cock pit moment' such as the 'take off' or landing of a plane (135), with all team members focused.

4.2.4.3 Decision 3. CT first or straight to OT or IR (Interventional Radiology)?

It is beneficial to have a pan-CT (CT Scan of the whole body) prior to surgery to aid decision making and clarify the injuries sustained. One question would be how much delay will be caused by getting a CT before surgery and can the patient tolerate this? The underlying question will also rotate around how likely is it that the CT results will alter this surgery?

4.2.4.4 Decision 4. If the patient is to be transferred to straight to operating theatre, which body cavity should be opened first?

This is vital prior to the start of surgery. The choreography of personnel in the operating theatre is highlighted in Figure 3.3 and a leadership handover will take place between the trauma team leader and the lead anaesthetist. This time the leader in theatre is the Consultant Anaesthetist who has the ability to be relatively 'hands off' at the head of the operating table and maintain situational awareness. Questions that the team leader must be aware of include where is the most time-critical injury? Is it possible to get proximal control of any bleeding (control of bleeding above the injury)? If there is pelvic or stab wound arterial bleeding is interventional radiology actually more appropriate than the operating theatre? Is it arterial bleeding that is not likely to respond to packing? Is there concurrent intra-abdominal bleeding requiring laparotomy? Communication amongst the team is vital to address these questions early so that patients are transferred to the correct location for treatment as soon as possible.

Figure 3.1 A trauma team at a trauma call will initially behave in the same manner as a Formula One Pit Crew. There are several sub-teams in operation.

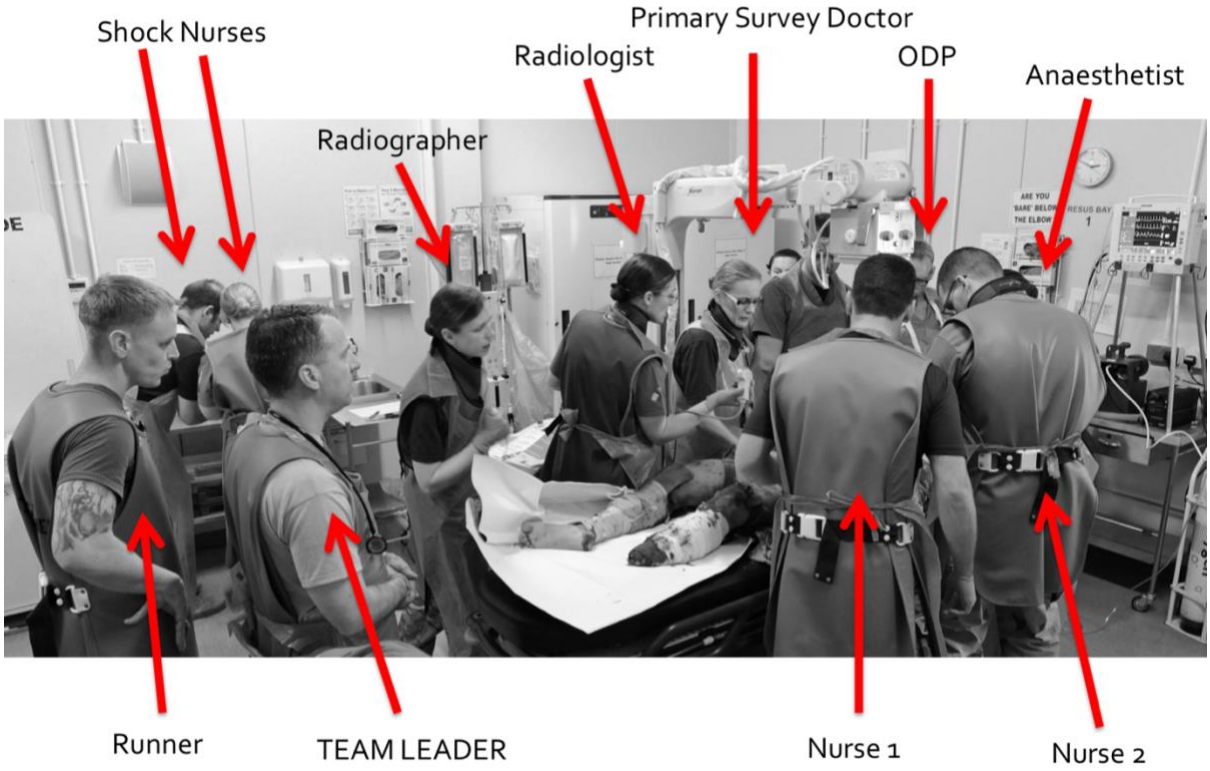


Figure 3.2 Trauma Team Members undertaking the primary survey using a horizonal approach to activity.

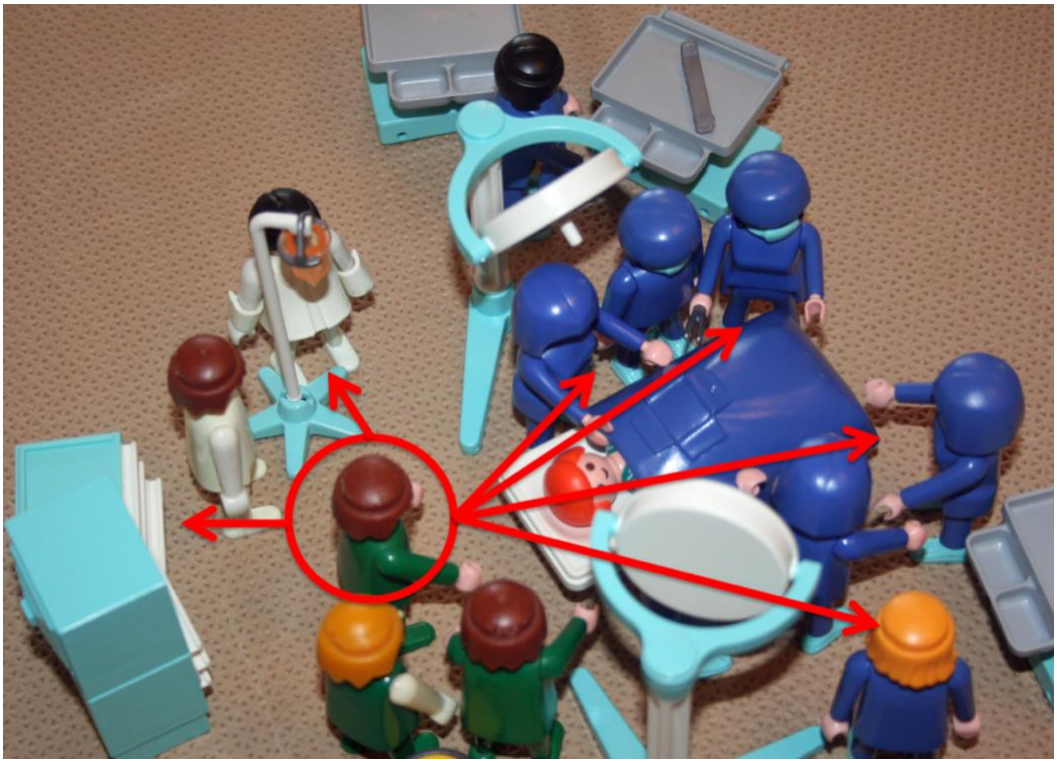


Figure 3.3 Position of team in the operating theatre. The Lead Anaesthetist (circled) is maintaining situational awareness

4.2.5 Conclusions

This article allowed the description of a common complex trauma call to highlight many of the human factors in trauma that were described in the first three sections of the thesis. This certainly has applied the knowledge to allow trauma teams in major trauma centres in England to use this model to improve patient care.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma Mercer SJ, Arul S, Pugh H, Midwinter MJ *Journal of the Royal Army Medical Corps* 2014; **160**: 105-108

3. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (60%) Original idea for manuscript, developed Trauma WHO, wrote 1st draft. S Arul (20%) developed Trauma WHO, subsequent revisions. H Pugh (20%) developed Trauma WHO, subsequent revisions.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
S Arul	Signed electronically Suren Arul 31.5.19	suren.arul@bch.nhs.uk
H Pugh	Signed electronically Harry	hpugh1@nhs.net

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	
	(Director of Studies/Advisor)		

6. Signature of Faculty Research Degrees Administrator

Signature:		Date:	
	(Faculty Research Degrees Administrator)		

Performance improvement through best practice team management: human factors in complex trauma

Simon Mercer,[1] G S Arul,[2] H E J Pugh[3]

ABSTRACT

Human factors or non-technical skills are now commonplace in the medical literature, having taken the lead from the airline and nuclear industries and more recently Formula One motor racing. They have been suggested as playing a vital role in the success of the trauma teams in recent conflicts. This article outlines the background to human factors, referring to early papers and reports and also outlines high profile cases that highlight their importance. We then describe the importance of human factors in the deployed setting and some of the lessons that have been learnt from current conflicts.

INTRODUCTION

The last 13 years have seen a busy operational period for the United Kingdom Defence Medical Services (UK-DMS) primarily supporting conflicts in Iraq (Op TELIC) and Afghanistan (Op HERRICK). Experience in both theatres of operation has led to many lessons learnt in the clinical management of complex trauma including the re-introduction of combat application tourniquets,[1] novel haemostatics[2] and near point coagulation testing.[3] A 'damage control resuscitation–damage control surgery' (DCR-DCS) sequence has also been developed to allow a seamless transition from the Emergency Department to the Operating Theatre and then Critical Care.[4] In addition to the technical aspects of dealing with complex trauma, much of the success of the current trauma team in the Role 3 Hospital in Camp Bastion, Afghanistan, has been linked to the exemplary human factors or non-technical skills within the 'Complex Trauma Team'.[5] This paper sets out to illustrate the importance of human factors in the deployed setting and to describe some of the lessons that have been learnt in current conflicts.

[1]Anaesthetic Department, Aintree University Hospital NHS Foundation Trust, Liverpool, UK; [2]212 Field Hospital, Sheffield, UK; [3]16 Medical Regiment, 144 Parachute Medical Squadron, Colchester, UK

Correspondence to Surg Cdr Simon Mercer, Anaesthetic Department, Aintree University Hospital NHS Foundation Trust, Longmoor Lane Aintree, Liverpool L9 7AL, UK; simonjmercer@hotmail.com

HUMAN FACTORS

The concept of human factors or 'non-technical skills' in healthcare have taken their lead from industry, in particular airline, nuclear, European railways and more recently Formula One motor racing. A common definition is '*the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance*'.[6] Catchpole *et al* have also defined human factors as a means of '*enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture, organization on human behaviour and abilities, and application of that knowledge in clinical settings*'.[7] The National Aeronautics and Space Administration was one of the first to realise that it was 'human factors' and not machine failures that were responsible for tragedies. They concluded that approximately 70% of errors investigated were attributable to failed communication, poor decision-making and ineffective leadership.[8] The development of 'the black box' (flight data recording system) further allowed the analysis of key conversations on the flight deck during critical incidents and a detailed examination of the behaviours of the flight crew. This work led to a culture change with all flight crew now being mandated to undergo regular human factors training termed 'crew resource management'.[9]

The seminal paper reviewing human factors in medicine is 'To err is human'[10] and has now been well publicised in the medical literature. A similar review in the UK led by the then Chief Medical Officer, Sir Liam Donaldson, showed similar trends in behaviour and culture.[11] Research into behaviours and attitudes in healthcare led to the development of frameworks for assessment and training in non-technical skills for anaesthetists,[12] surgeons[13] and scrub nurses.[14] These allow practice in training exercises and for debriefings to be conducted following critical incidents.

In the UK, initiatives such as 'patient safety week'[15] have highlighted the importance of human factors in clinical practice and raised their profile in the medical community. High profile cases have also highlighted the importance of human factors,[16] as have analysis of unanticipated critical incidents.[17] Two such cases are described in Box 1. There is evidence that more effective clinicians use first-rate non-technical skills as part of their working routine.[18] Important human factors in dealing with complex trauma include communication, situational awareness, leadership, followership and teamwork. For the UK-DMS, pre-deployment training on the Military Operational Surgical Training Course[19] and the Hospital Exercise[20] allow rehearsal and consolidation of this valuable corporate knowledge.

HUMAN FACTORS IN THE INITIAL ASSESSMENT OF THE CASUALTY IN THE EMERGENCY DEPARTMENT

The initial assessment and management of a casualty is under the control of Emergency Medicine Consultant who is the nominated team leader. The presence of a single identified trauma resuscitation team leader has been noted to lead to a better secondary survey, ATLS guideline adherence and team coordination.[24] The process of assessing the trauma patient, transferring to CT and then subsequent DCR is colloquially known as 'The Bastion Way' and is practiced during pre-deployment training. This allows members of the team to 'hit the ground running' as they might be asked to participate in a major trauma on their first day in the theatre of operations.[25]

The Complex Trauma Team is now a resource rich unit, the composition of which is outlined in Box 2 and allows 'consultant delivered care'. The team is often activated at least 20 min prior to the arrival of a seriously injured casualty. This allows time for the team leader to brief the team, determine names, roles and competencies, prepare contingency plans, check equipment and mentally rehearse any expected mental models.

On arrival of the casualty, the handover is given by the pre-hospital physician in exactly the same way every time. This is the age, time of injury, mechanism of injury, injuries sustained, signs and symptoms and treatment given (AT-MIST) handover and is outlined in Box 3. This is also rehearsed in pre-deployment training and allows the team to focus on listening to the handover so that they are all clear of the patient's injuries and physiology prior to any further interventions and key points and concerns are identified. This obviates the need for multiple repetitions,

Box 1 Two high profiles cases highlighting the importance of human factors in healthcare

Case of EB[21]

- On 29 March 2005, a 37-year-old woman attended for routine nasal surgery. Her pre-operative assessment revealed congenitally fused cervical vertebra but was otherwise unremarkable.
- Anaesthesia was induced with an infusion of remifentanil (0.3 μg/kg/min) and an intravenous injection of propofol 200 mg. There was difficulty inserting a laryngeal mask (LMA), so a further 50 mg of propofol was administered and a second attempt at insertion undertaken. Two sizes of LMA (sizes 3 and 4) were unsuccessfully attempted.
- Two minutes after induction of anaesthesia, the patient was cyanosed with an oxygen saturation (SaO_2) of 75% which dropped to 40% after 4 min. Attempts were made to ventilate the lungs with 100% oxygen using a facemask and oral airway but this proved difficult.
- Six minutes after induction of anaesthesia, SaO_2 remained at 40% and the patient's heart rate had dropped to 69 beats per minute. Atropine 0.6 mg and suxamethonium 100 mg were administered. A second consultant anaesthetist arrived to assist and a first attempt at tracheal intubation was made but it was impossible to view the laryngeal anatomy.
- Additional nursing staff arrived and an Ear, Nose and Throat (ENT) consultant.
- Ventilation remained extremely difficult—a situation described as '*can't intubate, can't ventilate*' in the Difficult Airway Society Guidelines.[22]
- Between 13 and 15 min after the induction of anaesthesia, further attempts at laryngoscopy and intubation were made by both consultant anaesthetists and an attempt was also made to perform a fibreoptic intubation.
- Between 16 and 20 min post-induction of anaesthesia, the ENT consultant attempted to intubate.
- After 20 min, an intubating LMA (iLMA) was inserted and attempts were made to insert an endotracheal tube though this.
- After 35 min post-induction of anaesthesia it was decided to abandon the procedure and the patient was transferred to the recovery area.
- She was later transferred to a Critical Care Unit in another hospital where she died 13 days later from a hypoxic brain injury.

A video reconstruction and discussion of this case are available on the Clinical Human Factors Group website (http://www.chfg.org) which demonstrates a breakdown in human factors in the anaesthetic room. There was a fixation error with intubation and not following the Difficult Airway Society Guidelines,[22] where an emergency cricothyroid airway would have been required following the declaration of '*can't intubate, can't ventilate*'. There was also a loss of situational awareness with the SaO_2 remaining very low for a significant period of time.

Case of GE[23]

- On 4 May 2006, a 45-year-old man underwent a surgical procedure to repair a fracture of a finger.
- The pre-operative assessment noted that the patient had a suspected hiatus hernia and suffered from oesophageal acid reflux; he also weighed 124 kg with a Body Mass Index of 40. There were no other problems encountered with the assessment of his airway. As the patient wished to have this procedure under general anaesthesia a decision was made to undergo a rapid sequence induction (RSI).
- Induction of anaesthesia was performed with 100 μg fentanyl, 500 mg thiopentone and 100 mg suxmethonium.
- It was impossible to view the larynx on the first attempt at laryngoscopy with a Macintosh Size 3 Blade and so a second attempt at intubation was made with a Polio Blade. At this time it was noticed that there was blood in the airway.
- A call for help was made after 3 min of induction of anaesthesia.
- An LMA was inserted and with an additional jaw thrust, ventilation was achieved.
- The anaesthetist decided to then attempt intubation via an iLMA and while this was inserted the SaO_2 dropped to 80%.
- It was difficult to pass an endotracheal tube through the iLMA, 1 mg of alfentanyl was administered and passage of a smaller ET tube was successfully attempted and the iLMA was removed.
- A decision was then made to insert a Cook Exchange Catheter through the ET tube and there were then several attempts to 'railroad' an ET tube over the Cook Exchange Catheter.
- Additional oxygen was attached to the Cook Exchange Catheter, but this was set at 15 litres per minute and surgical emphysema was noted immediately.
- A cricothyroidotomy was attempted.
- The patient then suffered a cardiac arrest and subsequently died.

This case also shows a deviation from the Difficult Airway Society Guidelines.[22] In a patient undergoing an RSI, once it was impossible to conventionally intubate the patient then he (according to the Guidelines) should have been woken up and intubation attempts terminated.

when those who were not listening or present realise that they have missed vital information.

At this moment and throughout the remaining time in the Emergency Department, the team leader has an important role in noise and crowd control. High levels of background noise have already been noted to be detrimental in team communication and cognition in the surgical team with an associated increased mortality in complex trauma operations.[27] Certain key moments such as the handover and intubation require complete silence, which are termed the 'sterile cockpit' in aviation. The concept of sterile cockpit reflects the requirement of the Aviation Safety Agency of the United States[28] where '*No command pilot, and no flight crew member may allow any other activity during a critical phase of the flight, which may confuse any flight crew member from the performance of his/her duties or to interfere in any way*

Box 2 Composition of a typical Complex Trauma Team (after[26]) (consultants are highlighted in bold)

- *Clinical Team*
  - **Team Leader (Emergency Consultant)**
  - Primary Survey Doctor (ED SpR)
  - **Anaesthetist 1 (airway)**
  - **Anaesthetist 2 (central venous access)**
  - ODP
  - Scribe (trauma nurse coordinator)
  - ED Nurse 1 (intravenous access and first blood sample)
  - ED Nurse 2 (drugs)
  - ED Nurse 3 (rapid infuser)
  - ED Nurse 4 (rapid infuser)
  - Runner
  - **Orthopaedic Surgeon**
  - **General Surgeon**
  - **Plastic Surgeon**
  - **Radiologist**
  - **Radiographer**
  - **Deployed Medical Director**
- *Logistic Support*
  - Laboratory Technician
  - Theatre Manager
  - Ward Master
- *Front of House*
  - Regimental Sgt Major
  - Interpreter
  - Padre

ED, Emergency Department; ODP, Operating Department Practitioner; SpR, Specialist Registrar.

in the performance of their duties.' For this reason, the handover is completed in silence and unless there is impending airway catastrophe or exsanguination, the patient is not touched by the trauma team.

The DMS have changed their assessment paradigm to <C> ABC[29] for battlefield injuries with a 'hands off' team leader coordinating them. Horizontal resuscitation is used for the primary survey so that it can be completed relatively quickly using concurrent activity.[30] This relies on a highly skilled and experienced team who display good followership. This has been defined as '*….the ability to effectively follow the directives and support the efforts of a leader to maximize a structured organization….*'[31] and ensures that all team members have a responsibility to proactively react to changing situations to support the team leader. In essence, this means that people are not standing still constantly waiting for instructions, but know their role in the team and are able to perform by holding their own mental models.

Box 3 AT-MIST handover

- A: Age of patient
- T: Time of injury
- M: Mechanism of injury
- I: Injuries sustained
- S: Signs and symptoms
- T: Treatment given

Situational awareness has been described as '*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future*'.[32] This concept is crucial in complex trauma as a patient's physiological state can change rapidly. There are three elements including gathering information, interpreting information and anticipating future states. The first of these comprises of information from the '9 liner', the AT-MIST handover and the initial Primary Survey. With a mental model from previous experience and predeployment rehearsal, the team leader can interpret all the information and plan future steps in the treatment pathway. In order to maintain situational awareness, the team leader must not become distracted by participating in technical tasks or touching the patient. A loss of situational awareness can be detrimental and lead to fixation errors and incorrect decision-making.

Another key human factor in complex trauma is communication. Communication was found to be a causal factor in 43% of errors made in surgery in three teaching hospitals in the USA.[18] To appreciate the importance of communication among the Complex Trauma Team and other supporting agencies in the hospital, the need to maintain situational awareness and continue with good leadership and followership, the following concepts were developed.[33]

- Command Huddle
  - A brief meeting of the senior clinicians to determine the immediate plan for the casualty (eg, to CT or theatre) or make decisions on futility.
- Snap Brief
  - A two-way communication between surgical and anaesthetic teams for the whole team in theatre to determine:
    - The clinical and imaging findings and the surgical plan.
    - Blood and blood products transfused and current rate of transfusion, coagulopathy and any other clinical problems.
- Sit-Reps
  - A regular update between anaesthetic and surgical teams which occurs every 15–30 min. A suggested sit-rep is shown in Box 4.

Box 4 Suggested sit-rep[33]

Anaesthetist
- The time since the start and the duration of the procedure
- Blood and blood products transfused
- The current rate of infusion of blood products
- Relevant blood gas results (particularly the pH and base excess), coagulopathy (ROTEM results) and temperature
- Any developing problems

Surgeon
- The surgical progress (eg, vascular control, therapeutic packing)
- Any new developing problems or findings
- Future intentions

CONCLUSIONS

Human factors play an important role in DCR-DCS in ensuring that key information is communicated accurately within the trauma and theatre teams to allow early robust decision-making and to avoid miscommunication and fixation errors. The challenge for the future will be to ensure that the current corporate memory is translated into contingency training and is also adapted for future facilities such as high readiness units and maritime platforms.

Acknowledgements We would like to thank Surgeon Commander Mark Midwinter CBE Royal Navy for his advice on the preparation of the manuscript.

Contributors SM: First draft, subsequent drafts, formatting for journal. GSA: Proof-reading, adding to and revising subsequent drafts. HEJP: Proof-reading, adding to and revising subsequent drafts.

Disclaimer The views in this article are of the authors only and not necessary those of the Ministry of Defence.

Ethics approval Not required. This is a personal view and summarises previous work.

Funding None.

Provenance and peer review Not commissioned; internally peer reviewed.

To cite Mercer S, Arul GS, Pugh HEJ. *J R Army Med Corps* 2014;**160**:105–108.

Received 7 November 2013
Accepted 10 November 2013
Published Online First 3 January 2014

J R Army Med Corps 2014;**160**:105–108.
doi:10.1136/jramc-2013-000205

REFERENCES

1 Brodie S, Hodgetts TJ, Ollerton J, *et al*. Tourniquet use in combat trauma: UK military experience. *J R Army Med Corps* 2007;153:310–3.
2 Kirkman E, Watts S, Hodgetts T, *et al*. A proactive approach to the coagulopathy of trauma: the rationale and guidelines for treatment. *J R Army Med Corps* 2007;153:302–6.
3 Doran CM, Woolley T, Midwinter MJ. Feasibility of using rotational thromboelastometry to assess coagulation status of combat patients in a deployed setting. *J Trauma* 2010;69S:S40–8.
4 Midwinter MJ, Woolley T. Resuscitation and coagulation in the severely injured trauma patient. *Philos T R Soc B* 2010;366:192–203.
5 Midwinter MJ, Mercer S, Lambert AW, *et al*. Making Difficult Decisions in Major Military Trauma: A Crew Resource Management Perspective. *J R Army Med Corps* 2011;157:S299–304.
6 Flin R, O'Connor P, Crichton M. Safety at the Sharp End: A Guide to Non-Technical Skills. *Ashgate* 2008:1.
7 Catchpole KR, Dale TJ, Hirst DG, *et al*. A multicenter trial of aviation-style training for surgical teams. *J Patient Safety* 2010;6:180–6.
8 Helmreich RL, Davies JM. Anaesthetic simulation and lessons to be learned from aviation. *Can J Anaesth* 1997;44:907–12.
9 Authority CA. CAP 737: Crew Resource Management (CRM) Training. Guidance for Flight Crew, CRM Instructors and CRM Instructor-Examiners. 2003:1.
10 Kohn LT, Corrigan JM, Donaldson MS, eds. *To err is human: building a safer health system*, National Academies Press, Washington, 2000.
11 Department of Health. *An Organisation with a Memory*. The Stationary Office, London. 2000:VII–XI.
12 Fletcher G, McGeorge P, Flin RH, *et al*. The role of non-technical skills in anaesthesia: a review of current literature. *Brit J of Anaesth* 2002;88:418–29.
13 Yule S, Flin R, Paterson-Brown S, *et al*. Development of a rating system for surgeons' non-technical skills. *Med Educ* 2006;40:1098–104.
14 Mitchell L, Flin R. Non-technical skills of the operating theatre scrub nurse: literature review. *J Adv Nurs* 2008;63:15–24.
15 http://www.patientsafetyfirst.nhs.uk/content.aspx?path=/ (accessed 5 Nov 2013)
16 Bromiley M. Have you ever made a mistake? *R Coll Anaesth Bull* 2008;48:2442–5.
17 Cook TM, Woodall N, Frerk C, *et al*. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. *Brit J of Anaesth* 2011;106:617–31.
18 Gawande A, Zinner MJ, Studdert DM, *et al*. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003;133:614–21.
19 Mercer SJ, Whittle C, Siggers B, *et al*. Simulation, human factors and defence anaesthesia. *J R Army Med Corps* 2010;156:365–9.
20 Arora S, Sevdalis N. HOSPEX and concepts of simulation. *J R Army Med Corps* 2008;154:202.
21 The case of Elaine Bromiley. http://www.chfg.org/resources/07_qrt04/Anonymous_Report_Verdict_and_Corrected_Timeline_Oct_07.pdf (accessed 29 Oct 2013).
22 Henderson JJ, Popat MT, Latto IP, *et al*. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004;59:675–94.
23 Sheriffdom of glasgow and strathkelvin under the fatal accidents and sudden deaths (Scotland) ACT 1976. Determination of Sheriff Linda Margaret Ruxton in Fatal Accident Inquiry into the death of Gordon Ewing. http://www.scotcourts.gov.uk/opinions/2010FAI15.html (accessed 29 Oct 2013).
24 Townsend RN, Clark R, Ramenofsky ML, *et al*. ATLS-based videotape trauma resuscitation review: education and outcome. *J Trauma* 1993;34:133–8.
25 Mercer SJ, Whittle CL, Mahoney PF. Lessons from the battlefield: human factors in defence anaesthesia. *Brit J of Anaesth* 2010;105:9–20.
26 Mercer SJ, Tarmey NT, Woolley T, *et al*. Haemorrhage and coagulopathy in the Defence Medical Services. *Anaesthesia* 2012;68:49–60.
27 Einstein GO, McDaniel MA, Williford CL, *et al*. Forgetting of intentions in demanding situations is rapid. *J Exp Psychol: Appl* 2003;9:147–62.
28 Federal Aviation Regulations (FARA, 14CFR) Part 121 Section 542 available at http://www.flightsimaviation.com/data/FARS/part_121-542.html (accessed 27 December 2013).
29 Hodgetts TJ. ABC to <C> ABC: redefining the military trauma paradigm. *Emerg Med J* 2006;23:745–6.
30 Horne S, Smith JE. Preparation of the resuscitation room and patient reception. *J R Army Med Corps* 2011;157:S267–72.
31 Bjugstad K, Thach EC, Thompson KJ, *et al*. A fresh look at followership: A model for matching followership and leadership styles. *J Behav Appl Manag* 2006;7:304–19.
32 Endsley MR. Toward a theory of situation awareness in dynamic systems. *Human Factors: The J Hum Factors Ergon Soc* 1995;37:32–64.
33 Arul GS, Pugh H, Mercer SJ, *et al*. Optimising Communication in the Damage Control Resuscitation-Damage Control Surgery Sequence in Major Trauma Management. *J R Army Med Corps* 2012;158:82–4.

4.3 Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma. MERCER SJ, Arul S, Pugh H *Journal of the Royal Army Medical Corps* 2014; 160: 105-108

4.3.1 Why this paper was written?

This article puts into context the improvements that were achieved in the management of military casualties during recent conflicts in Iraq and Afghanistan. I deployed to both of these war zones as part of the complex trauma team and a subsequent analysis performed by Penn-Barwell and colleagues revealed a year on year improved survival (Figure 1.1) (5). The article starts with a summary of the important aspects of human factors taken from the airline industry and key reports (22,23) that I have discussed in the introduction to the thesis and also summarises the cases of Elaine Bromley (28) and Gordon Ewing (136) to set the scene. The article describes a military trauma call in Camp Bastion summarising the importance of human factors throughout the trauma call. A knowledge transfer paper was required to inform serving members of the Defence Medical Services about the advances in Human Factors in military complex trauma that had been made so that these lessons learnt could be continued in future deployments.

4.3.2 What was known at the time of writing?

The pre-deployment training of UK-DMS personnel is intensive and can take up to one year prior to deployment. There is individual training on technical skills and small group simulations on the Military Operational Surgical Training Course (13) and then a 'collective' large scale group training on the Hospital Exercise (HospEx) (12). HospEx itself is held in a converted aircraft hangar that is laid out exactly as the hospital in Afghanistan was. The exact equipment and paperwork are also present to allow teams to rehearse the flow of patients in real time. This exercise is geared to ensure that the hospital unit itself is deemed fit to deploy, but also that individuals are ready to 'hit the ground running' when arising in the theatre of operations, sometimes being required to start work on the night of arrival.

All members of the UK-DMS work in the NHS and are embedded in the Major Trauma Centres in England. They are then deployed for a period of up to 3 months every 6-18 months depending on their role (137). The importance of preparation and appreciation of human factors is paramount as they will be working within different teams (sometimes multinational) using military specific equipment, protocols and standard operating procedures. The patients also have a different pattern of injury not experienced in the NHS with blast accounting for 54% of injuries in one review and high velocity gunshot wounds up to 30% (138). The patient population is also different consisting of predominantly young, fit males who have often sustained high and multiple traumatic amputations. The severity of injury is also much greater than seen in peace times with over 50% of casualties in one review having an injury severity score between 36 and 75 (138).

4.3.3 What the paper added or contributed to the 'global' clinical community?

This article describes a typical military trauma call and emphasises the importance of the human factors that have been described previously to ensure the rapid and successful assessment and treatment of a casualty. This article also follows on from a discussion paper (14) that lead to the development of the concept of 'the Trauma WHO' that was tested in Camp Bastion and is described earlier in this thesis (42). It has been cited 22 times, but many of these citations are further work that I have been involved in and I have used this article to develop further work streams. Human factors play an important role in damage control resuscitation, particularly in ensuring that key information is communicated accurately to allow early robust decision-making and to avoid miscommunication and fixation errors. The contents of this article formed the basis for the introductory human factors training on the Military Operational Surgical Training Course (13).

I have presented the ‘Trauma WHO’ at several invited national meetings that I have listed already, and it has also now become embedded in the work we do in my own civilian major trauma centre. The communication elements are now a vital part of the Damage Control Surgery process (64).

4.3.4 Where are we now?

The ‘Trauma WHO’ is now an integral part of the patient pathway at my own institution. This is particularly useful for patients who have undergone complex trauma and require immediate surgery within 4 hours of admission. We continue to practice the ‘Trauma WHO’ every 3 months on our ‘in house’ high fidelity trauma simulation course (8). The ‘Trauma WHO’ has been adopted in several other institutes with a Military presence such as Derriford Hospital and there has been interest when I have presented at national conferences. The mainstream adoption of such checklists has previously been resisted and my own observations of mandating the WHO checklist itself was initially very unpopular amongst some clinicians in the NHS.

Despite the ‘Trauma WHO’ being tested and evaluated in an active field hospital in a war zone (42) it has still not been globally adopted in Major Trauma Centres in England. In order to provide further evidence and convince other trauma clinicians a multi-centre observational study would need to be organised. This would review times to making decisions and over all 24-hour and 30-day mortality in groups of matched patients who are treated using and not using this communication tool.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for each publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

3. Title of Research Output

Gleeson S, Groom P, Mercer SJ. Human Factors in Complex Airway. British Journal of Anaesthesia Education 2016; 16: 191-197

4. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (60%) - inital idea for publication, 1st draft and subsequent drafts
S Gleeson (20%), literature review and manuscript review, P Groom (20%), manuscipt revisions and subsequent drafts

5. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
S Gleeson		gleesonsuzie@hotmail.com
P Groom		petergroomx@yahoo.com

6. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature: Date:

(Director of Studies/Advisor)

7. Signature of Faculty Research Degrees Administrator

Signature: Date:

(Faculty Research Degrees Administrator)

BJA Education Advance Access published September 25, 2015

OXFORD

Revalidation FOR ANAESTHETISTS RCA Revalidation matrix. Matrix reference 1102, 1103, 2A01, 3A01

BJA Education, 2015, 1–7

doi: 10.1093/bjaed/mkv045
Advance Access Publication Date: 6 October 2015

Human factors in complex airway management

S Gleeson MBChB FRCA[1], P Groom BMedSci MBBS, FRCA[2], and S Mercer MBChB MAcadMEd FHEA FCollT FRCA MMEd[2,*]

[1]Advanced Airway Fellow, Aintree University Hospital, Liverpool, UK and [2]Consultant Anaesthetist, Anaesthetic Department, Aintree University Hospital, Liverpool L9 7AL, UK

*To whom correspondence should be addressed. Tel: +44 7970153168; E-mail: simonjmercer@hotmail.com

Key points

- Human factors are vital to the successful management of an anticipated difficult airway.
- Careful planning and preparation are key to success, with a logical strategy being selected and the airway management being undertaken by a competent anaesthetist.
- Careful consideration of the risks of each technique will assist a thorough preoperative assessment to be undertaken, and the logical plan and equipment selected.
- A detailed pre-anaesthetic briefing of the multidisciplinary team is required to ensure that all personnel are aware of the plan and their role in the anaesthetic room.
- Situational awareness is vital to ensure that fixation errors are avoided. Disciplined communication and thoughtful followership ensure good team dynamics.

Human factors have been defined as 'the environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety'[1] and have been described with particular relevance to anaesthesia in the Anaesthetists Non-Technical Skills Framework.[2] When dealing with a patient with a complex airway, exceptional attention to human factors is vital to success. This has been noted extensively in the literature after two high profile cases.[3,4] Recently, there has been adoption of human factors in healthcare at the highest level with the signing of a Concordat from the National Quality Board by organizations such as the General Medical Council, The Care Quality Commission, and Health Education England.[5]

The Fourth National Audit Project of the Royal College of Anaesthetists (NAP4) examined major complications in airway management and concluded that poor human factors could have contributed to 40% of the cases reported. In 25% of these cases, inadequate human factors were felt to be a major contributor to a poor outcome.[6] Further analysis specifically looking at human factors in cases reported to NAP4 reported that there were potentially an average of four human factors issues per reported case.[7] This article sets out to describe our experience of the importance of human factors when dealing with patients with an 'anticipated difficult airway' and describes our strategy, particularly in planning, preparing, briefing the team, and conducting the airway management with an illustrated example.

Our hospital experience

Aintree University Hospital NHS Foundation Trust is a large teaching hospital situated in North Liverpool. It is a tertiary referral centre for head and neck surgery providing specialist services to around 1.5 million residents in Merseyside, Cheshire, South Lancashire, and North Wales. The population served by Aintree includes some of the most socially deprived communities in the country, with high levels of illness. The Head and Neck Unit is the largest in the UK, carrying out ~800 cases per year. This provides our anaesthetists and surgeons with a wealth of experience in dealing with patients with abnormal airway anatomy and frequently, difficult airways. Our department is the home to the nationally recognized Aintree Difficult Airway Management (ADAM) course.[8]

Specific human factors in complex airway management

Leadership

It is important that the team is aware as to who is in charge of the case. The leader will usually (although not always) be the most experienced anaesthetist and their role is to:

- Formulate the airway management plan(s) and communicate this to the team, so they are all 'on the same page'.
- Allocate roles with the team and identify any limitations in skill mix.
- Maintain situation awareness and not become task fixated while the airway is being secured.
- Define the trigger points for moving from Plan A to B (and subsequent plans) if required.

Teamwork

Good teamwork is integral to success in all airway management. This is particularly important in the anticipated difficult airway. Salas and colleagues[9] described a team as 'a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal, who have each been assigned specific roles or functions to perform, and who have a limited life-span membership'. It is therefore very important that the team is aware of the plan(s) for airway management, their role in the process, and anything else that is expected of them. A team brief will ensure that this is achieved with an opportunity to ask questions and clarify any differences in opinion.

Situation awareness

Situation awareness itself has been described as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future'.[10] Loss of situation awareness is one of the most common recurring features in adverse incidents involving airway management.[7] The three stages of situational awareness include:

- Gathering information. This will start with taking a history and examining the patient and will be supplemented by other investigations such as nasendoscopy, CT scan, and discussion with surgical colleagues. Once airway management occurs then further information is gathered from monitors, images on fibreoptic cameras, and tactile feedback. Mistakes may occur if the individual misinterprets task-relevant information.
- Interpreting the information. Mistakes may occur if an individual wrongly perceives specific information.
- Anticipating future states. Mistakes may occur if future status is wrongly predicted, either from a poor initial mental model or personal memory failure. (A mental model is an explanation of a person's thought process, or what they expect to happen.)

Good situation awareness when performing a complex task can be maintained in different ways. In the trauma team scenario, the trauma team leader (TTL) maintains a 'hands off' approach and stands at the foot of the bed so they maintain an all round view and are effectively 'driving the bus'.[11] In this way, the TTL is not directly involved in any practical tasks themselves and so are able to observe the patients management in 'real time'.

Decision-making

After assessment of the patient before operation, the clinician should identify the potential difficulties and problem areas for that individual. The risks and benefits of each potential airway management method need to be weighed up. These may vary from case to case. The location of the planned intubation, experience level of staff available, and clinical urgency of the case are all factors that may deem a normally suitable technique, unsuitable. Once a decision has been made and 'Plan A' formulated, it is important to continue to re-evaluate the clinical situation taking into account any significant changes and ensuring that 'Plan A' remains the best plan.

Although the Plan A, B, and C approach is favoured, it is important to recognize that some airway cases are such that there may only be one plan. In such circumstances, the most senior anaesthetist will manage the airway and if this is devolved to a senior trainee, it must be done under close and direct supervision with a clear plan for stepping in.

Followership

Although good leadership is crucial to good teamwork, so too is good followership. A follower is defined as anyone not acting in the position of leader and responding to organizational actions; a person who is active rather than passive.[12] In terms of difficult airway management, this encompasses actions such as anticipation, support of the team leader, and good communication using feedback loops. A feedback loop is where the sender (e.g. the team leader) transmits an instruction to another member of the team who receives it and then feeds back they have understood the instruction (or decoded the message correctly).

Communication

Good communication is paramount to the successful execution of securing the patient's airway and simple steps can ensure that communication flows from the team leader to the other members of the team. Previous work by Gawande and colleagues[13] cited communication failures as being responsible for 43% of errors in three large teaching hospitals in the USA. We have found a team brief to facilitate good communication among the multi-disciplinary team

The team brief allows:

- introduction of team members,
- the team to be reminded of individual levels of training and competencies,
- allocation of tasks,
- discussion of potential problems and highlighting solutions,
- clarification of the team leader's mental model and the airway plan(s).

There are several aspects of communication skills that should be highlighted, particularly in the management of the patient with an anticipated difficult airway.

- 'Sterile Cockpit': During the intubation attempt, the team should aim for what is described in the airline industry as a 'sterile cockpit'. This infers that the noise level is kept to an absolute minimum by having only the required team members present. This enables all monitors, comments, and instructions to be heard clearly ensuring vital information is not lost.

Case history

The importance of human factors in the management of an anticipated difficult airway will be illustrated by the case described in Table 1.

Fascial space infections (dental abscesses) can be considered the archetypal anticipated difficult airway;[14] they can be life-

Table 1 Case history

A 62-yr-old male presented to The Accident and Emergency Department with acute dysphagia for liquids arising on a background of a 3 week history of worsening toothache and facial swelling
On examination, he was pyrexial (39°C), dysarthric, and was drooling as he could not swallow his saliva. He also could not assume the supine position
He had trismus with 1 cm of mouth opening, swelling and erythema over his left cheek, and mandible spreading to the left anterolateral aspect of his neck. He had an old fracture of his nose
He was tachycardic (110 beats min^{-1}) but not hypotensive. His Sa_{O_2} was 92% on room air. Nasendoscopy revealed only the left nares to be patent. The anatomy of the oropharynx at nasendoscopy was found to be severely distorted, full of secretions and with a mucosa prone to contact haemorrhage. The glottis could not be visualized. A full blood count revealed a leucocytosis, and clotting abnormalities

threatening and cause serious postoperative problems. They are heterogenous in their presentation, and can involve the whole upper airway and all the access routes into the airway.

The anticipated difficult airway is different from the management of the unanticipated difficult airway. The anaesthetist knows there are going to be problems in advance and consequently has time to select the best intubation plan to deal with their patient's particular constellation of problems. It is crucial that the plan is enacted precisely, necessitating attention to detail at every step of the intubation plan from positioning and oxygenation through to confirmation of tube placement in the trachea.

The anaesthetist must have a pragmatic approach to assessment, planning, and execution of the intubation plus the human factors involved at each stage. To this end, we advocate a six-step method used by the ADAM website[8] if time allows.

Aintree six-step approach to difficult airway management

Q1: How much time do I have?
Q2: What access to the airway is available (nose, mouth, trachea)?
Q3: How compromised is the airway?
Q4: Which fascial spaces are involved?
Q5: Which management plan(s) best fits the circumstances?
Q6: Could I make the situation worse? If so, how?

Question 1

Difficult airways are time critical emergencies and can be classified as follows:

(i) No time for assessment and planning: Need to act immediately to avoid hypoxic brain injury/death. Correct use of the DAS algorithms[15] is crucial to outcome.
(ii) Some time for assessment and planning: The six-step approach is used remembering that actions can gain or lose time; airway management is a fluid situation with often incomplete information and so it is necessary to take stock repeatedly and avoid being too rigid in one's approach.
(iii) Adequate time for assessment and planning. A structured approach is required to assess options, evaluate risk, and maximize success. We use the ADAM website[8] and methodology and it is used for illustration here, although of course other methods may be used.

Questions 2–4

The available access routes are first considered. Airway compromise is multi-factorial and for this patient, sepsis indicates urgency, influences management, and is associated with more complications. Trismus is not always due to pain: the joint may be compromised. Pharyngeal involvement causes stridor, drooling, dysphagia, and tongue immobility. Nasendoscopy is the most important investigation. It is simple to perform, confirms nasal patency, and indicates the location of airway distortion and the degree of oedema. Imaging is useful if the patient can lie flat as it accurately defines the fascial spaces involved, differentiates between cellulitis and abscess, reveals vascular sheath involvement, and confirms the diagnosis of mediastinitis if suspected clinically.

Question 5

Once assessment and investigation are completed, the clinician uses the information to decide which airway management plan best fits the patients' circumstances. Airway management should not follow a 'one size fits all' approach. The breadth of techniques means a 'bespoke' plan should be sought that is best suited to deal with the problems at hand. A good way to do this is by considering the limitations of each plan in the context of the patient's problems. When using the ADAM website, each choice of technique is evaluated against the clinical scenario and an analysis of limitations, potential complications, and likely success is used to identify the technique that is most likely to succeed without complications

Question 6

The last step considers how one's actions can make the situation worse. This is done by constructing an intubation plan detailing potential pitfalls and to discuss it with the whole team in advance. The ADAM website generates a printable 'contingency plan' (Table 2) splitting the intubation into its constituent steps and listing the anticipated problems for each step. The left-hand column lists generic potential problems likely to be encountered whenever the equipment is used, in this case awake fibreoptic intubation. The right-hand column highlights how the patient's problems are likely to cause difficulty and at which stage in the intubation this may arise. Used at the team brief, it enables everyone to effectively be on the 'same page'; when to expect specific problems, how they will manifest themselves. Table 2 does not provide solutions but rather highlights potential pitfalls leaving it to the user to formulate a response. It also determines in advance when it would be appropriate to abandon the procedure and consider other options (if any).

How the patient was managed

Assessment and planning

The severe trismus and indurated anterior neck meant that there was only one viable route into the airway: the

Table 2 Contingency table for the patient described in Table 1

Generic problems	Patient-specific problems
1. Check equipment/position patient	
Adverse patient position	
Inadequate nasal patency	
Illumination not satisfactory	
Monitor image not optimized	
Wrong size tube	
Wrong type of tube	
2. Prepare nares, oxygenate, start sedation	
Omit supplemental oxygen	
Increasing airway obstruction (LA effect)	
Apneoa (excess sedation)	
Respiratory depression (excess sedation)	
3. Mount tracheal tube on fibrescope	
Tube not loaded	
Tube loaded via Murphy's eye	
Tube/fibrescope interface not lubricated	
Omit anti-fog solution	
4. Negotiate fibrescope through the nose	Operator traumatizes nasal mucosa causing bleeding: coagulopathy
Fogging of lens	
Secretions obscure view	
Inadequate nasal patency	
Traumatic bleeding obscures view	
Friable tissue obscures view (e.g. polyp)	
Disorientation	
Failure to traverse nose	
Nasal congestion/hyperaemia	
Naso-pharyngeal obstruction (e.g. adenoids)	
5. Explore pharynx, larynx, and trachea	Contaminant obstruction:
Epiglottis obscures glottis	spontaneous or iatrogenic abscess rupture
View becomes 'red out' (blood) or 'white out' (secretions)	iatrogenic bleeding
Prolapsing pharyngeal wall obscures view	Airway distortion (cellulitis)
Excessive vocal cord movement	
Excessive reflex glottic closure	
Unexpected gastric reflux	
Accumulating pharyngeal secretions	
6. Position fibrescope in trachea	
Carina not realized	
7. Railroad tracheal tube over fibrescope into trachea	Tube advancement problem: nares, epiglottis, arytenoid, subglottic
Tube not loaded/loaded incorrectly	Bleeding: trauma, abscess rupture
Tube diameter too large to enter nostril	
Tube/fibrescope step problem	
Tube hold up: nostril, epiglottis, arytenoids, or subglottically	
Inadvertant removal of fibrescope from trachea	
8. Confirm tube position relative to carina	
Cannot identify carina	
Patient distress due to iatrogenic total airway obstruction	
9. Remove fibrescope leaving tracheal tube	
Difficult fibrescope removal (no lubrication)	
10. Re-confirm tube position with CO_2/bag movement	
No capnograph trace	
No ventilation	
Difficult ventilation	
11. Induce anaesthesia and inflate cuff	
Inadvertent loss of i.v. access	
12. Confirm bilateral lung ventilation	
Ruptured tube cuff	
Endobronchial intubation	
Difficult ventilation	

left nostril. Awake fibreoptic intubation was considered the only option (awake tracheostomy would have been very difficult).

Preparation

All equipment was prepared and checked in advance. The patient was told why an awake intubation was necessary so that they

Table 3 Airway team

Name	Role
Consultant anaesthetist	Airway team leader Responsible for final plan based on all the available information Ultimately responsible Conducts team brief Supervises advanced trainee
Advanced trainee (ST6–7) in Anaesthesia	Perform the airway management within their competency under the supervision of the consultant anaesthetist Helps formulate the airway management plan
Intermediate trainee anaesthetist (ST3) in anaesthesia	Perform sedation using TCI remifenanil Induces patient once position of the tracheal tube has been confirmed
Operator department practitioner	Prepare the airway equipment Assist the anaesthetist undertaking the airway management
Support worker	Act as a 'runner' should an emergency arise or additional equipment is or help is needed
Consultant ENT surgeon	Contributes to the airway management plan Undertake an emergency surgical airway if indicated Perform a rigid laryngoscopy if indicated Support the anaesthetic team
ENT speciality trainee (ST4)	Work under the supervision of the ENT Consultant and perform the roles of the ENT consultant under their supervision
Theatre nurse	Has available equipment ready to allow an immediate surgical airway or rigid bronchoscopy. Needs to be ready in the operating theatre

understood the reasoning behind the decision and what the procedure actually involved. We also explained that the nature of his infection would mean he would be kept sedated and ventilated on ITU for between 12 and 48 h to allow his airway to improve before extubation.

We do not premedicate with benzodiazepines nor do we administer anti-sialogues; in a case such as this, they will be ineffectual. We do prepare the nares with a topical vasoconstrictor to minimize bleeding from the turbinate's vessel-rich mucosal bed and avoid any concomitant topical local anaesthetic. We believe that the use of local anaesthetic in this instance could worsen the airway.[16] Our technique for AFOI has previously been described using single-agent sedation with target-controlled infusion (TCI) remifentanil to facilitate awake fibreoptic intubation,[17] but this may be considered controversial by other anaesthetists in the UK and is just one technique. It provides analgesia and sedation and we believe it is more likely to preserve upper airway reflexes than topicalization with local anaesthetics. This advanced airway technique should not be used for the first time on a complex case without first gaining experience in lower risk cases.

It is advisable to anaesthetize such patients on the operating table rather than a trolley. The former allows better patient positioning, better access to the patient for the anaesthetist (and surgeon should a surgical airway be necessary), and reducing the chance of an accidental extubation when transferring the anaesthetized patient. A decision was also made as to where to manage the airway: in the anaesthetic room or in the theatre itself? The advantage of the anaesthetic room is privacy while the advantage of theatre is its space and lighting should a surgical airway be needed. We elected to anaesthetize the patient in theatre.

All cases of anticipated difficulty should have their neck surface anatomy assessed beforehand. In this case, the thyroid and cricoid cartilages were impalpable because of overlying induration and swelling. The neck itself felt 'woody' in terms of its poor tissue compliance and immobility. This alerted us to the fact that a surgical airway would be a difficult undertaking.

Team briefing

The introduction and implementation of the WHO Surgical Checklist has been reported to reduce in-hospital 30 day mortality.[18] We implemented a team brief at the start of each operating list led by the consultant anaesthetist. In this instance, he clearly stated that this was a 'high stakes' airway with only one clear route of access (LEFT nostril) and that an awake fibreoptic intubation would be performed. Using the ADAM contingency plan (Table 2), it was made clear that bleeding was a real threat and that should the AFOI be abandoned, it would be due to bleeding or the inability to railroad the tracheal tube. In such circumstances, it was extremely unlikely that the sedation could be aborted and the patient returned to full consciousness with a clear airway. In which case, a surgical airway would be needed and that this would be difficult to perform. The composition of the 'airway team' is described in Table 3.

Managing the airway

The patient was arranged in an upright sitting position on the operating table as the patient did not tolerate lying down. Nasal spectacles were fitted and oxygen commenced at 15 litre min^{-1}. I.V. access was obtained and an infusion of Hartmann's solution commenced. The sedationist titrated the TCI remifentanil while maintaining constant verbal communication; the endpoint being a drowsy but cooperative patient. The sedationist was then tasked with monitoring the patient and not the image of the patient's airway on the monitor. Remifentanil has a profound effect on respiration; the patient can be awake but apneoic. The sedationist placed a hand on the patient's chest to assist respiratory monitoring and if movement stopped, he prompted the patient to breathe.

Once the patient had achieved an appropriate level of sedation, the airway operator instructed the ODP to load a warmed 6.0 nasal RAE tube onto a lubricated fibrescope. We ensured the scope had not traversed the Murphy's eye and taped the pilot

balloon tubing to the tube adjacent to the connector so it could not dangle across the patient's face and eyes. Anti-fog solution was carefully applied to the lens of the scope, then the position of the prong of the nasal spec in the left nostril adjusted to allow the scope to enter the nose and the procedure began.

The nostril was easily traversed without traumatizing to the mucosa, but once the oropharynx was entered, no anatomical landmarks could be identified due to tissue oedema and collections of secretions. However, by only advancing the scope into black airspace, the operator soon found himself in the trachea, despite the lack of any recognizable intervening anatomy. The scope was then held in the mid-trachea, avoiding contact with the carina (which could trigger coughing) while preparations were made to deliver the tracheal tube.

The scope was handed to the ODP, who was then instructed to hold its position in the trachea. The airway operator lubricated the tip and cuff of the tube before using two hands to gently advance the tube into the nostril ensuring the bevel faced laterally and so was less likely to traumatize the turbinates. Once through the nostril, the tube was rotated 90° clockwise so the bevel faced the epiglottis (minimizing hold up). Should hold up be experienced the tube would have been rotated 180° anti-clockwise so the bevel now faced the arytenoids: the next point of hold up. Once the tube had entered the trachea, we confirmed its position visually before smartly removing the scope, allowing the patient to breathe easily again as the oedematous airway had been completely occluded by the scope and tube. The anaesthetic circuit with 100% oxygen at 15 litre min^{-1} was attached, bag movement and most importantly CO_2 trace observed before anaesthesia was induced with propofol, and surgery commenced. The lowest recorded Sa_{O_2} during the procedure was 93%. I.V. dexamethesone was administered.

Intraoperative management

The surgeons incised and drained the collections. The erythema and induration on the anterior neck extended towards the sternoclavicular joints, its extent outlined with a marker pen. As airway oedema is expected to worsen in the first 12–48 h after operation, we elected to keep him intubated and sedated. However, before transferring him to the critical care unit, we performed a CT scan to exclude the diagnosis of mediastinitis (suspected in view of the extensive cellulitis and the degree of sepsis). No collection was seen.

Postoperative care

After operation, we closely monitored the airway by nasendoscopy and had a low threshold for re-imaging if considered necessary. Regular reviews were made of microbiology, surgical drains, and whether all sources of infection had been removed. The decision to extubate was taken after 36 h once the airway oedema had resolved. During the interim, great care was taken by nursing staff to avoid accidental extubation.

Extubation strategy

Extubation can be considered as, if not more, challenging than intubation.[19] Consideration was given as to where the extubation should take place: critical care or the operating theatre? In our institution, critical care has the equipment and the personnel with the experience to deal with a patient such as this. A Cook Staged Extubation kit was utilized to facilitate blind reintubation as this was an 'at risk' extubation according to the DAS guidelines.[19]

After siting the kit's guide wire under direct vision with a fibrescope and preoxygenation, the patient was sat up and extubated easily under remifentanil sedation (so that the patient was awake and tolerating the tube with appropriate reflex suppression), leaving the guide wire in place. The extubation was successful, and the patient remained on the critical care unit for another 12 h with the staged extubation guide wire *in situ* before it was removed and the patient discharged to the ward. Should the patient have required re-intubation, the Cook re-intubation catheter would have been advanced over the guide wire into the trachea and used as a bougie to facilitate rapid blind reintubation.

Summary

Human factors are vital in the safe and successful management of a patient presenting with an anticipated difficult airway for a surgical procedure. Careful planning and preparation are essential and rely on an accurate history and examination supplemented by specialist imaging such as nasendoscopy. It is important to determine the 'best plan' as sometimes there is only one plan. A team brief allows all members to be aware of their roles and responsibilities and to be on the 'same page' and this must be multi-disciplinary. Clear communication is vital not only with initial intubation but throughout the whole case with an airway team leader coordinating activities and facilitating decision-making.

Declaration of interest

S.M. and P.G. are both faculty members of the Aintree Difficult Airway Management Course. Neither have any financial gain from this course.

References

1. Health and Safety Executive. *Reducing Error and Influencing Behaviour*. *HSG48*. London: HSE books, 1999; 2
2. Fletcher GC, McGeorge P, Flin RH *et al*. The role of non-technical skills in anaesthesia: a review of current literature. *Br J Anaesth* 2002; **88**: 418–29
3. The case of Elaine Bromiley. Available from http://www.chfg.org/resources/07_qrt04/Anonymous_Report_Verdict_and_Corrected_Timeline_Oct_07.pdf (accessed 29 October 2013)
4. Sheriffdom of Glasgow and Strathkelvin under the fatal accidents and sudden deaths (Scotland) ACT 1976. Determination of Sheriff Linda Margaret Ruxton in Fatal Accident. Available from http://www.scotcourts.gov.uk/opinions/2010FAI15.html (accessed 29 October 2013)
5. National Quality Board. Human Factors in Healthcare: A Concordat from the National Quality Board. London: NHS England, 2013. Available from http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf (accessed 21 February 2015)
6. Shaw J, Frerk C, Russell J. A commentary on human factors aspects of cases reported to NAP 4. In: Cook TM, Woodall N, Frerk C, eds. *Fourth National Audit Project of the Royal College of Anaesthetists and Difficult Airway Society. Major Complications of Airway Management in the United Kingdom. Report and Findings*, Chapter 24. London: Royal College of Anaesthetists, March 2011; 193–201
7. Flin R, Fioratou E, Frerk C *et al*. Human factors in the development of complications of airway management:

preliminary evaluation of an interview tool. *Anaesthesia* 2013; **68**: 817–25
8. The Aintree Difficult Airway Management Course. Available from http://adam.liv.ac.uk/adam8/login.aspx (accessed 21 February 2015)
9. Salas E, Dickinson TL, Converse S *et al*. Toward an understanding of team performance and training. In: Swezey RW, Salas E, eds. *Teams: Their Training and Performance*. Norwood: Ablex, 1992; 3–29
10. Endsley M. Toward a theory of situational awareness in dynamic systems. *Hum Factors* 1995; **37**: 32–64
11. Mercer S, Park C, Tarmey NT. Human factors in complex trauma. *BJA Education* 2014; doi: http://dx.doi.org/10.1093/bjaceaccp/mku043
12. Rost J. *Leadership for the Twenty-First Century*. Prague: Westport, 1993
13. Gawande AA, Zinner MJ, Studdert DM *et al*. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003; **133**: 614–21
14. Darshane S, Groom P, Charters P. Responsive contingency planning: a novel system for anticipated difficulty in airway management in dental abscess. *Br J Anaesth* 2007; **99**: 898–905
15. Henderson JJ, Popat MT, Latto IP *et al*. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004; **59**: 675–94
16. Ho AM, Chung DC, To EW, Karmakar MK. Total airway obstruction during local anesthesia in a non-sedated patient with a compromised airway. *Can J Anaesth* 2004; **51**: 838–41
17. Vennila R, Hall A, Ali M *et al*. Remifentanil as primary agent to facilitate awake fibreoptic nasal intubation: an observational study. *Br J Anaesth* 2010; **104**: 522P
18. Van Klei WA, Hoff RG, Van Aarnhem EEHL *et al*. Effects of the introduction of the WHO 'Surgical Safety Checklist' on in-hospital mortality: a cohort study. *Ann Surg* 2012; **255**: 44–9
19. Mitchell V, Dravid R, Patel A. Difficult Airway Society guidelines for the management of tracheal extubation. *Anaesthesia* 2012; **67**: 318–40

4.4 Human Factors in Complex Airway Gleeson S, Groom P, MERCER SJ. *British Journal of Anaesthesia Education* 2016; 16: 191-197

4.4.1 Why this paper was written?

I have previously outlined The Fourth National Audit Project of the Royal College of Anaesthetists (NAP4) which set out to examine major complications in airway management. Despite not being the primary intention, the reviewing panel concluded that poor human factors probably contributed to 40% of the cases reported. In 25% of these cases, inadequate human factors were felt to be a major contributor to a poor outcome (139). A further analysis concluded that there was probably an average of four human factors issues per reported case (65) which puts the importance of human factors into perspective. These findings demonstrate the importance of human factors in the management of the difficult airway in emergency anaesthesia and complex trauma and this is why I wanted to write an article to publicise and bring to the attention of anaesthetists working in centres in the United Kingdom who may come into contact and treat patients who have anticipated difficult airways. This was an invited peer reviewed article for the *BJA Education Journal* and I am the senior author.

4.4.2 What was known at the time of writing?

This article translates the knowledge that was previously recognised by creating guidelines for the management on penetrating airway injuries (113) and the systematic review into the management of non-iatrogenic airway trauma (95) that have been described already in this thesis. The key point is that the airways described in this context are ‘anticipated difficult airways’ and thus rely on a different approach to their management. The concepts of leadership, teamwork and decision making are described with the roles of the team leader and individual team members.

4.4.3 What the paper added or contributed to the 'global' clinical community?

Our current practice is to use a team brief to ensure that all team members have situational awareness at the start of the case and understand the mental model. The Aintree six-step approach to difficult airway management includes the following six questions and the use of a contingency table helps to consolidate ideas and formulate the plan and this is vital to communicating to the whole team the plan and mental model for each case. I have presented this work at the Difficult Airway Society Annual Scientific Meeting in December 2017; this is the largest difficult airway meeting in Europe attended by over 200 delegates. This work is also part of the Aintree Difficult Airway Management Course (ADAM Course), a nationally recognised difficult airway that trains up to 200 delegates per year and has been running for over 10 years.

- Q1: How much time do I have? – no time, some time, adequate time
- Q2: What access to the airway is available (nose, mouth, trachea)?
- Q3: How compromised is the airway?
- Q4: Which fascial spaces are involved?
- Q5: Which management plan(s) best fits the circumstances?
- Q6: Could I make the situation worse? If so, how?

4.4.4 Where are we now?

This article translates knowledge around human factors in anticipated difficult airway that was previously published in an original research article (113) and a systematic review (95). The concept of the anticipated difficult airway is potentially life threatening and requires exceptional human factors amongst the team leader and their followers with exemplary leadership, teamwork and decision making.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	Simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

Title of Research Output

Human Factors in Contingency Operations. Mercer SJ, Khan M, Scott T, Matthews J, Henning D, Stapley S *Journal of the Royal Army Medical Corps* 2017: 163; 78-83

3. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (50%), original idea, 1st draft of paper and subsequent drafts. M Khan (10%) surgical section and subsequent drafts. T Scott (10%) manuscript revision and prehospital care. J Matthews (10%) logistics and manuscript revisions. D Henning (10%) Emergency Medicine and manuscript revisions. S Stapley (10%) orthopaedic section and manuscript revisions.

4. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
M Khan		mansoorkhan@nhs.net
T Scott		timscott4@me.com
J Matthews		jonathanmatthews@nhs.net
D Henning		danielhenning@mac.com
S Stapley		sarahstapley@btinternet.com

5. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature:		Date:	

	(Director of Studies/Advisor)		
6. Signature of Faculty Research Degrees Administrator			
Signature:		Date:	
	(Faculty Research Degrees Administrator)		

Human factors in contingency operations

Simon J Mercer,[1] MA Khan,[2] T Scott,[3] JJ Matthews,[4] DCW Henning,[5,6] S Stapley[7]

ABSTRACT

The UK Defence Medical Services are currently supporting contingency operations following a period of intensive activity in relatively mature trauma systems in Iraq and Afghanistan. Among the key lessons identified, human factors or non-technical skills played an important role in the improvement of patient care. This article describes the importance of human factors on Role 2 Afloat, one of the Royal Navy's maritime contingency capabilities, and illustrates how they are vital to ensuring that correct decisions are made for patient care in a timely manner. Teamwork and communication are particularly important to ensure that limited resources such as blood products and other consumables are best used and that patients are evacuated promptly, allowing the facility to accept further casualties and therefore maintain operational capability. These ideas may be transferred to any small specialist team given a particular role to perform.

INTRODUCTION

A '*contingency*' operation is defined in the Oxford English Dictionary as '*a future event or circumstance which is possible but cannot be predicted with certainty*' and described by a military author as '*our Forces training but not deploying*' on a specific operation.[1] The nature of these future operations is currently unknown, but it is likely to require UK Defence Medical Services (DMS) personnel to work in remote and austere environments at different echelons of care. Those in secondary care will be deployed at either Role 2 or Role 3 providing support to 127 Squadron (16 Medical Regiment), Role 2 Land Based (in support of the British Army and Royal Marines), Role 2 Afloat (R2A), Vanguard Role 3 Field Hospital and the Primary Casualty Receiving Facility (RFA ARGUS).

For more than a decade, the DMS was operational in both Iraq (Operation TELIC) and Afghanistan (Operation HERRICK) with a busy caseload of patients with complex trauma who suffered predominately blast injuries from improvised explosive devices and high-energy ballistic injuries. The majority of this caseload was managed in a mature trauma system in a purpose-built facility that was described as '*exemplary*' by external peer review.[2] A number of factors, including refinement of surgical techniques,[3] the use of blood and blood products,[4] a damage control resuscitation and damage control surgery (DCR-DCS) sequence,[5] administration of tranexamic acid[6] and advances in physician-led pre-hospital care,[7] all lead to a significant improvement in survival rates as the conflict matured.[8] It is also considered that human factors played an important role in the improvement in patient care.[9] Deploying personnel underwent training and rehearsal before leaving the UK on the Military Operational Surgical Training (MOST) Course[10] and the Hospital Exercise (HOSPEX), which was a macro-simulation of the entire hospital unit performed immediately prior to deployment.[11]

Human factors are described as '*enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture and organisation on human behaviour and abilities and application of that knowledge in clinical settings*'[12] and also as '*the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance*'.[13] The importance of human factors on previous operations has been described,[9 14] as have some of the difficult decisions that were experienced in this environment.[15] Human factors also refer to team resource management and include elements such as teamwork, leadership, followership, communication and situational awareness with individual systems developed for anaesthetists,[16] surgeons[17] and scrub practitioners.[18] This paper concentrates on the importance of human factors on a Role 2 Afloat (R2A) platform, as the authors have considerable recent experience in this environment, but the concepts are readily transferable to other small teams deployed either on military contingency operations or on civilian disaster relief settings.

ROLE 2 AFLOAT

The modern configuration of R2A has already been described[19] and the composition of the team is noted in Box 1. The anaesthetic[20] and surgical[21] aspects of the R2A have also previously been described in detail but essentially the available personnel allow damage control resuscitation[22] to be conducted within the confines of their scaled equipment and drugs (referred to as '*the 370 module*' which is adapted for the maritime environment). It includes sufficient team members to enable consultant-delivered care to be achieved for two seriously injured casualties arriving at the same time with one surgical operating table and two critical care beds; this is denoted by the configuration 2-1-2 (two emergency department bays, one operating table, two critical care beds). It is key that the deployed team support the emergency

Box 1 Configuration of the Role 2 Afloat team

- Consultant in Emergency Medicine
- Emergency Medicine Nurse 1
- Emergency Medicine Nurse 2
- Emergency Medicine Nurse 3*
- Consultant Anaesthetist 1
- Consultant Anaesthetist 2
- Consultant General Surgeon
- Consultant Orthopaedic Surgeon
- Operating Theatre Practitioner/Theatre Nurse 1
- Operating Theatre Practitioner 2
- Operating Theatre Practitioner 3
- Biomedical Scientist
- Radiographer
- Critical Care Nurse 1
- Critical Care Nurse 2
- Critical Care Nurse 3
- Medical Assistant*
- ±Medical and Dental Servicing Technician

*These personnel, along with a nominated physician, also form the Maritime In-Transit Care (MITC) team.

[1]Department of Anaesthesia, Aintree University Hospital NHS Foundation Trust, Liverpool, UK; [2]Imperial College Healthcare NHS Trust, London, UK; [3]University Hospitals North Staffordshire NHS Trust, Stoke-On-Trent, UK; [4]Department of Orthopaedics, Royal Cornwall Hospitals NHS Trust, Truro, UK; [5]Plymouth Hospitals NHS Trust, Plymouth, UK; [6]Academic Department of Military Emergency Medicine, Royal Centre for Defence Medicine (Research & Academia), Medical Directorate, Birmingham, UK; [7]Medical Directorate (Research and Academia) ICT Centre, Birmingham, UK

Correspondence to Surg Cdr Sarah Stapley, Medical Directorate (Research and Academia), ICT Centre, Birmingham Research Park, Vincent Drive, Birmingham, B15 2SQ, UK; sarahstapley@btinternet.com, sarahstapley@o2.co.uk

medicine consultant who is the nominated team leader with impeccable followership defined as '*the ability to effectively follow the directives and support the efforts of a leader to maximize a structured organization*'.[23]

WHAT ARE THE DIFFERENCES IN WORKING ON ROLE 2 AFLOAT?

Clinical

The well-resourced complex trauma team described in Camp Bastion Trauma Hospital[9] has been reduced in numbers and thus team members are required to undertake less familiar roles (eg, general and orthopaedic surgeons are required to perform a primary survey) and have reduced rest periods when it is busy. There is also the risk of clinicians becoming isolated if they are the only person in their particular field of expertise. Personnel may not have deployed in this environment before and may need to prepare for short notice deployments, perhaps without a predetermined end date and with individuals they have not worked with before.

In a resource-limited environment (equipment, blood products, personnel, space), there will be capacity, resilience and ethical implications attached to clinical decisions that were previously not encountered. Early decision making on where and how the patient will be evacuated is important to ensure that they receive their ongoing and enhanced treatment in a timely manner and that the R2A facility is ready to receive more casualties if required. All clinicians have difficult decisions to make as offensive operations may be compromised if the medical facility cannot receive casualties. The emergency physician has to decide if and when to activate massive transfusion protocols, how to manage more than two casualties and be capable of leading multiple trauma resuscitations in different locations within the medical complex. The anaesthetists need to decide whether a rapid sequence induction (RSI) of anaesthesia is required as, if undertaken, that casualty will be a much greater burden upon limited resources and will reduce the number of personnel available for other activities. The surgeons need to decide if an operation is required and when it is required: with limited surgical sets, there must be an emphasis on life, limb and sight-threatening injuries only. In the event of multiple casualties requiring surgery, then a decision will need to be made as to which patient to operate on first. This may mandate the use of the T4 (expectant) triage category in the UK or friendly forces, which will be both a novel and an emotionally challenging process.

Equipment

The equipment on R2A is made up of those items present in the 370 Afloat module and thus there is no CT scanner or near-point testing of coagulation (eg, RoTEM). This may require a change in clinical practice, as investigations from both of these were previously integral to the DCR-DCS sequencing.[5] Appreciation of the limited available resources is important: there is a limited stock of blood products with an uncertain resupply chain and surgical sets are also limited, although sterilisable. The resource constraint will require careful communication within the team facilitated by the clinical director to ensure that '*everyone is on the same page*' and has equal situational awareness in terms of clinical delivery and that those choices that are made represent the best use of available resources.

Patient pathway

Key human factors are present at almost every stage of the patient pathway[24] and those pertinent to R2A are depicted in Figure 1. Working in a maritime platform adds its own integral problems such as a moving ship, limited space, noise and also the ship's own power supply, which will need to cope with high voltage equipment such as the Dragon (Xography, UK) X-ray machine. DMS personnel must also be well versed in emergency actions onboard such as fire fighting and damage control.

Usually, notification of a casualty will be via a signal to the ship and a decision will be made as to how the casualty will be brought onboard. This will typically be via a helicopter to the flight deck but could also be via a boat transfer or even from within the ship in the case of an onboard incident. The whole R2A team will be activated at this point and be briefed by the team leader. Communication with the biomedical scientist will occur at this point regarding the potential issue of a '*shock pack*': locally, this will be two units of universal donor packed red cells and two units of universal donor fresh frozen plasma (FFP) but a further issue can be made including cryoprecipitate, if carried and required.

Following sanitisation of the patient (removal of weapons by an onboard reception team), the R2A team must carefully transfer the patient to the hospital facility. In the emergency department, immediate checks for signs of life, catastrophic haemorrhage and airway compromise are quickly completed before the patient is handed over by the prehospital team. Once complete, the primary survey is undertaken by the team in their designated roles in a ABC format (catastrophic haemorrhage, airway, breathing, circulation[25]) coordinated by the team leader who is responsible for maintaining and updating the team's situational awareness ('*the perception of the elements in the*

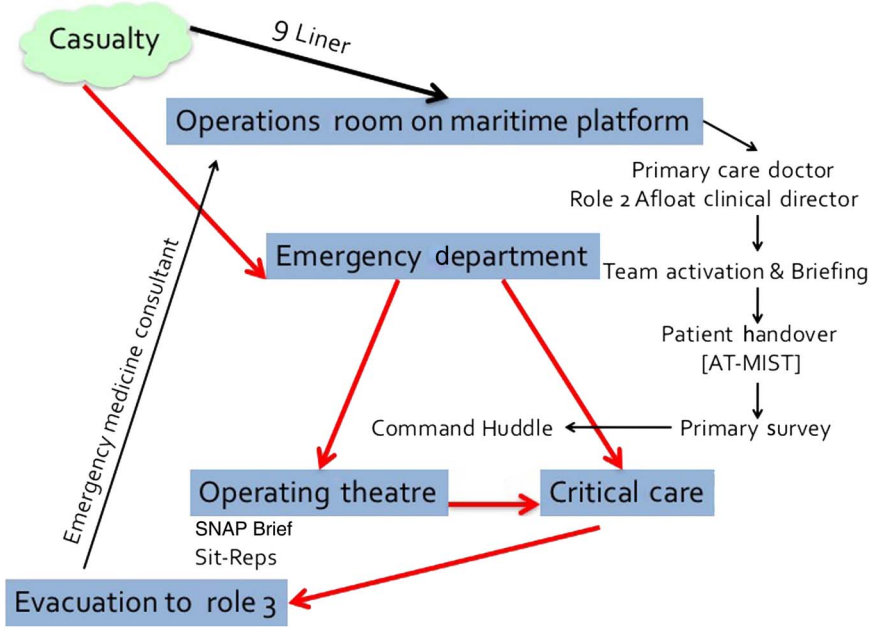


Figure 1 Human factors involved in the patient pathway on a R2A unit. Casualty movements are shown in red and lines of communication in black. AT-MIST, Age, Time of Injury, Mechanism of Injury, Injuries Sustained, Signs and Symptoms and Treatment Given.

Figure 2 Role 2 Afloat trauma team working in the resuscitation bay on a maritime platform. © Crown copyright 2016. Reproduced with the permission of the Controller of Her Majesty's Stationery Office/Queen's Printer for Scotland and Ministry of Defence.

environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future[26]'). In situations where more than one casualty requires surgery, emergency department personnel must be prepared to have a role in optimising their condition with support from the intensive care team as required. The resuscitation bay and trauma team working is outlined in Figure 2.

In order to optimise communication in complex trauma, the '*Trauma WHO*'[27] (Table 1) was developed. Once the primary and secondary surveys are complete and initial investigations are taken, the '*Command Huddle*' will take place. Because of the limited space in the trauma bay, all personnel will be able to hear this important conversation where effectively the lead clinicians plan the casualties' ongoing treatment. This might entail a primary transfer to intensive care to await further transfer or if a surgical procedure is required, then the patient will need to be transferred into the operating theatre and positioned on the operating table. Prior to any further activity, the second part of the Trauma WHO is undertaken where the patient's identity is confirmed, the mechanism of injury, injuries sustained and relevant investigations repeated and then the surgical and anaesthetic plans stated. It is helpful to write down the surgical plan on the white board in theatre and the triggers to move from plan A to plan B and plan C if this is appropriate. Once surgery is underway, then regular '*SIT-REPS*' are required. When this was tested in a clinical operational environment,[14] it was felt that these should only be undertaken when there was new information to share with the group and might be at a frequency of every 10–30 min. Recently, the mnemonic for the sit-rep has been changed to STACK (Lt Col Harry Pugh, Personnel communication) (Table 2), as this is relatively easy to remember. Following handover to critical care, a debrief of the team will occur.

Once the patient has left the emergency department, the emergency physician must liaise with the ship or Battlestaff in order to ensure appropriate signal traffic has taken place and that an appropriate Role 3 facility has been identified. Timelines for evacuation must be decided early and an appropriate evacuation asset identified. The evacuation team can then be identified, so they may begin their preparations.

To illustrate the importance of human factors on a deployed R2A unit, two fictional case scenarios are described (Tables 3 and 4).

Table 1 The Trauma WHO

1	Command Huddle
2	SNAP Brief
3	SIT-REPS
4	Debrief

DISCUSSION OF CASE 1

On a deployed R2A platform, equipment is limited: only essential modalities are carried. With this scenario, there is a spectrum of clinical signs and symptoms which largely depend on the exact intra-abdominal injury, the evacuation timeline, critical decision-making timelines and the casualty's physiological response to the injury.

There is no thromboelastrography available to determine the exact nature of any potential coagulopathy and no platelets are carried. Therefore, the clinicians are limited to 1:1 resuscitation (packed red blood cells (PRBC):FFP) with supplementation by cryoprecipitate and recombinant factor VIIa. This is an important factor to consider when dealing with such casualties in a deployed environment as blood products will be limited and the resupply chain may not be immediate. Provision may have been made for an emergency donor panel on the ship and this should be activated as soon as possible.

Once it has been identified that the casualty requires an operation, it is imperative that no delays in care are made. The priority in damage control resuscitation is to use damage control surgery as a haemorrhage-arresting manoeuvre while restoring circulating volume. Constant communication between the anaesthetist and the surgeon is of paramount importance to determine whether:

A. Surgical control of haemorrhage has been achieved, allowing the anaesthetist to volume resuscitate with blood products.
B. Surgical control has been achieved, but the patient is not responding to physiological measures, that is, non-surgical bleeding.
C. Surgical control cannot be achieved and the patient's physiological parameters are deteriorating, with increasing demand of blood products.

Adherence to the Trauma WHO[27] is vital and regular '*sit-reps*' will ensure that all members of the team are aware of the stage of DCR-DCS.

While surgery is underway, the emergency medicine consultant will liaise with the command of the ship as to how the

Table 2 Sit-rep mnemonic

S	Systolic BP
T	Temperature
A	Acidosis
C	Coagulation
K	Kit (including blood products used)

Table 3 A gunshot wound (GSW) to the abdomen in a UK serviceman

Background	The R2A is accommodated in RFA MOUNTS BAY in support of an amphibious operation. It is supported by an allied nation Role 3 Hospital that can be reached by a 1-hour flight. It currently has 11 damage control surgery surgical sets, 20 units of packed red blood cells (PRBC), 20 units of fresh frozen plasma and 10 units of cryoprecipitate. Six general damage control sets available which can address damage control laparotomy, thoracotomy, vascular shunt or named vessel repair, stabilise pelvis and fasciotomise a limb with additional supplementary three damage control surgery debridement sets and two damage control surgery neurosurgical sets.
Preparation	Radio communication to RFA MOUNTS BAY Ops Room that a UK serviceman has sustained a GSW to the abdomen. The R2A team is activated and assembles in the hospital facility. The team is briefed by the team leader (emergency medicine consultant). In view of the likelihood that damage control resuscitation will be required, an initial '*shock pack*' is ordered (two PRBC and two FFP). The Belmont Rapid Infuser and other equipment are prepared.
Handover of patient	A—25 years T—1700 M—GSW I—wound in right iliac fossa; another wound in right upper back S—HR 110 bpm, BP 90/60 mm Hg T—one large bore cannula into right antecubital fossa, 500 mL crystalloid given, morphine 10 mg intravenously
Initial findings and initial actions	Primary survey findings: Airway patient; good bilateral air entry but decreased excursion on the right; generalised abdominal tenderness and peritonism; GCS 15; temperature 35.1°C. CXR—no pneumothorax seen on supine film. Pelvis X-ray—normal. Venous blood gas results—Hb 9.0 g/dL, pH 7.20, lactate 4.5. Administration of co-amoxiclav 1.2 g, tranexamic acid 1 g, ketamine 20 mg.
Command Huddle	Decision is made to undertake a trauma laparotomy. Further four PRBC, four FFP and two cryoprecipitate requested.
Transfer to theatre SNAP Brief	SNAP Brief Patient identification and injuries verified. No identified projectile on X-ray, so tract will likely follow the trajectory between two wounds. Likely colonic injury with possibility of renal, hepatic and diaphragmatic injury. May require large volume resuscitation if extensive solid organ injury. Will require chest drain on right side. *Plan A*: If colonic injury, irrespective of contamination, given blood loss and acidaemia, the bowel will be left in discontinuity with an open abdomen until physiology corrected. *Plan B*: As per plan A but with limited solid organ injury, requiring <4 units PRBC/FFP, then haemostasis to be achieved and packing performed until physiology corrected. *Plan C*: If extensive solid organ injury and likelihood of high volumes of PRBC, then revisit at 5 units PRBC transfusion, if ongoing bleeding not amenable to surgical correction, then Command Huddle to discuss likelihood of survival.
Ongoing theatre progress	Intubation—fentanyl 70 μg, ketamine 70 mg, rocuronium 70 mg. *Surgical findings* GSW through ascending colon with gross faecal contamination and a grade 2 renal laceration on superior pole of right kidney. Right hemicolectomy performed and left in discontinuity. Right kidney explored, no intervention required. Open abdomen with '*Opsite sandwich*'. Right-sided chest drain inserted—small amount of blood and air released. Diaphragmatic wound repaired. Emergency medicine consultant liaises regarding evacuation of patient from R2A.
Transfer to critical care	Packaging for transfer

FFP, fresh frozen plasma; RFA, Royal Fleet Auxiliary.

casualty is best evacuated. This is important for two reasons: the patient will require further treatment in a Role 3 facility and, with a 2-1-2 configuration, casualty throughput is hindered if evacuation is delayed. It is important to decide who will escort the patient as he will undoubtedly remain intubated and ventilated for transfer. A physician-led transfer will reduce the medical staff of the facility by 20% and will therefore have a significant impact on capability.

DISCUSSION OF CASE 2

This case illustrates a number of issues when managing patients at Role 2 and also in the maritime environment. Potentially, if there was immediate onward evacuation to a Role 3 facility available with a reasonable transfer time, then this patient may not have required any emergent treatment at R2A and would benefit from direct transfer to Role 3 for definitive treatment. In this situation, there is no immediate transfer available, so treatment is required at R2A. At Role 2, '*less is often more*' and it is important that the limited resources are not taken up with prolonged surgical procedures which are not required at this echelon of care. In the Command Huddle, the decision is made to take the patient to theatre. The patient initially is clinically stable although during the SNAP Brief it is recognised that there is potential for the patient to deteriorate, in particular the potential for the development of compartment syndrome is recognised. The surgical plan is to use Plaster of Paris to splint the fracture although the team has been warned that external fixation may be required.

It is important that there is constant communication about evacuation plans throughout as the need for a prolonged hold of the patient may influence the surgeons' decisions in theatre.

The patient is extubated postoperatively as there is no reason to keep the patient intubated for transfer. This also means that there is no need for a physician to accompany the patient during transfer meaning that medical manpower will not be compromised.

SUMMARY

The R2A environment provides a unique maritime platform to allow consultant-delivered damage control resuscitation and surgery to be performed followed by transfer to a higher echelon of care. We have described how attention to human factors is vital to ensure that both the correct decision is made for patient care in a timely manner and that the facility remains operational. Such considerations are transferable to any of the small teams in DMS

Table 4 Compound fracture to left leg following a fall from a height

Background	The R2A is accommodated in RFA MOUNTS BAY in support of an amphibious operation. It is supported by an allied nation Role 3 Hospital 1 hour's flying time away. It currently has six damage control surgery surgical sets, 12 units of packed red blood cells, 12 units of fresh frozen plasma and 6 units of cryoprecipitate.
Preparation	Radio communication to RFA MOUNTS BAY Ops Room that a UK serviceman has fallen from a height and sustained an open fracture to the left leg. This was bleeding and a combat-application-tourniquet (CAT) has been applied. The R2A team is activated and assembles in the hospital facility. The team is briefed by the team leader (emergency medicine consultant).
Handover of patient	A—25 years T—1700 M—fall from 6 feet I—deformity of left lower leg with anterolateral wound S—HR 100 bpm BP 110/80 mm Hg T—CAT applied at 1630 with Sam-Splint
Initial findings and initial actions	Primary survey findings CAT released: no neurovascular compromise and no ongoing haemorrhage; therefore, pneumatic tourniquet is applied, but not inflated. Airway patient; normal bilateral air entry; soft abdomen; anatomically intact pelvis; long bones clinically intact. Open fracture—wound communicates with fracture site, no gross contamination, no clinical signs of compartment syndrome. CXR—normal. Pelvis X-ray—normal. X-ray left leg—displaced, simple fracture midshaft left tibia and fibula. Venous blood gas results—Hb 11.0 g/dL, pH 7.35, lactate 2.0. Administration of co-amoxiclav 1.2 g, tranexamic acid 1 g, ketamine 20 mg.
Command Huddle	Decision is made to undertake an emergency debridement and splintage of open fracture left tibia/fibula. No current need for blood products but patient grouped and saved.
Transfer to theatre SNAP Brief	SNAP Brief Patient identification and injuries verified. Isolated open fracture left lower leg. No requirement for large volume resuscitation. *Plan A*: Debridement and washout of open wound with splintage of fracture in above knee Plaster of Paris (POP). *Plan B*: As per plan A but if fracture very unstable and large soft tissue injury, consider fixation of fracture with external fixator. *Plan C*: As per plan A but if develops any signs of compartment syndrome, then will require lower leg fasciotomies and fixation of fracture with external fixator.
Ongoing theatre progress	Intubation—fentanyl 70 μg, ketamine 70 mg, rocuronium 70 mg. *Surgical findings* Clean wound with direct communication to fracture site. Limited debridement necessary with healthy muscle and no signs of compartment syndrome. Fracture stable once reduced. Wound dressed with dry gauze and splinted with above knee POP. Foot pulses present at end of procedure. Femoral and sciatic nerve blocks applied and patient extubated at end of procedure. Emergency medicine consultant liaises regarding evacuation of patient from R2A.
Transfer to critical care	Packaging for transfer

required to undertake contingency operations. Consideration should be made by medical planners on the individuals present in the team as disruptive personalities could destroy team dynamics.[15] Teamwork and communication are particularly important to ensure that limited resources such as blood products and other consumables are not wasted and that patients are evacuated to allow the facility the opportunity to accept further casualties. As the team leader, the emergency medicine consultant is responsible for maintaining situational awareness and feeding back information to the whole team in the emergency department. This process is continued in theatre by adoption of the Trauma WHO.[27]

Contributors SJM is responsible for the overall content and is guarantor; had the initial idea and wrote the first draft. MAK wrote Case 1 and discussion and contributed to subsequent drafts. JJM and SS wrote Case 2 and discussion and contributed to subsequent drafts. DVWH wrote the second draft and subsequent corrections. TS contributed to subsequent drafts. All authors discussed the article at length during a series of meetings and discussions while deployed on RFA MOUTS BAY in January 2016.

Competing interests All authors are serving members of HM Forces.

Provenance and peer review Not commissioned; externally peer reviewed.

To cite Mercer SJ, Khan MA, Scott T, *et al*. *J R Army Med Corps* Published Online First: [*please include* Day Month Year] doi:10.1136/jramc-2016-000658

Received 5 May 2016
Accepted 10 May 2016

J R Army Med Corps 2016;**0**:1–6.
doi:10.1136/jramc-2016-000658

REFERENCES

1 Henderson J. A British perspective on future contingency operations. In: Kümmel G, Giegerich B, eds. *The armed forces: towards a post-interventionist era?* Fachmedien Wiesbaden: Springer, 2013: 143–7.
2 Care Quality Commission. *Defence medical services: a review of compliance with the essential standards of quality and safety*. London, 2012:1–36.
3 Ramasamy A, Hinsley DE, Edwards DS, *et al*. Skill sets and competencies for the modern military surgeon: lessons from UK military operations in Southern Afghanistan. *Injury* 2010;41:453–9.
4 Mercer SJ, Tarmey NT, Woolley T, *et al*. Haemorrhage and coagulopathy in the Defence Medical Services. *Anaesthesia* 2012;68:49–60.
5 Midwinter MJ, Woolley T. Resuscitation and coagulation in the severely injured trauma patient. *Philo T Roy Soc B* 2010;366:192–203.
6 Morrison JJ, Dubose JJ, Rasmussen TE, *et al*. Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) Study. *Arch Surg* 2012;147:113–19.
7 Blackbourne LH, Baer DG, Eastridge BJ, *et al*. Military medical revolution. *J Trauma* 2012;73:S372–7.
8 Penn-Barwell JG, Roberts SAG, Midwinter MJ, *et al*. Improved survival in UK combat casualties from Iraq and Afghanistan. *J Trauma* 2015;78: 1014–20.
9 Mercer S, Arul GS, Pugh HEJ. Performance improvement through best practice team management: human factors in complex trauma. *J R Army Med Corps* 2014;160:105–8.
10 Mercer SJ, Whittle C, Siggers B, *et al*. Simulation, human factors and defence anaesthesia. *J R Army Med Corps* 2010;156:365–9.
11 Arora S, Sevdalis N. HOSPEX and concepts of simulation. *J R Army Med Corps* 2008;154:202.
12 Catchpole KR, Dale TJ, Hirst DG, *et al*. A multicenter trial of aviation-style training for surgical teams. *J Patient Saf* 2010;6:180–6.
13 Flin R, O'Connor P, Crichton M. *Safety at the sharp end*. Cornwall, UK: Ashgate, 2008.
14 Arul GS, Pugh H, Mercer SJ, *et al*. Human factors in decision making in major trauma in Camp Bastion, Afghanistan. *Ann Surg* 2015;97:262–8.
15 Midwinter MJ, Mercer S, Lambert AW, *et al*. Making difficult decisions in major military trauma: a crew

resource management perspective. *J R Army Med Corps* 2011;157:S299–304.
16 Flin R, Patey R, Glavin R, *et al*. Anaesthetists' non-technical skills. *Brit J Anaes* 2010;105:38–44.
17 Yule S, Flin R, Paterson-Brown S, *et al*. Non-technical skills for surgeons in the operating room: a review of the literature. *Surgery* 2006;139:140–9.
18 Mitchell L, Flin R. Non-technical skills of the operating theatre scrub nurse: literature review. *J Adv Nurs* 2008;63:15–24.
19 Risdall JE, Heames RM, Hill G. Role 2 Afloat. *J R Army Med Corps* 2011;157:632–4.
20 Mercer SJ, Heames RM. Anaesthesia and critical care aspects of Role 2 Afloat. *J R Nav Med Serv* 2013;99:140–3.
21 Tye S, Carnie R, Chambers R, *et al*. The surgical aspects of Role 2 Afloat. *J R Nav Med Serv* 2013;99:146–8.
22 Jansen JO, Thomas R, Loudon MA, *et al*. Damage control resuscitation for patients with major trauma. *Br Med J* 2009;338:1436–40.
23 Bjugstad K, Thach EC, Thompson KJ, *et al*. A fresh look at followership: a model for matching followership and leadership styles. *J Behav Appl Manag* 2006;7:304–19.
24 Mercer S, Park C, Tarmey NT. Human factors in complex trauma. *BJA Education* 2015;15:231–6.
25 Hodgetts TJ. Mahoney PF, Russell MQ, *et al*. ABC to ABC: redefining the military trauma paradigm. *Emerg Med J* 2006;23:745–6.
26 Endsley MR. Toward a theory of situation awareness in dynamic systems. *Hum Factors* 1995;37:32–64.
27 Arul GS, Pugh HE, Mercer SJ, *et al*. Optimising communication in the damage control resuscitation-damage control surgery sequence in major trauma management. *J R Army Med Corps* 2012;158:82–4.

4.5 Human Factors in Contingency Operations. MERCER SJ, Khan M, Scott T, Matthews J, Henning D, Stapley S *Journal of the Royal Army Medical Corps* 2017: 163; 78-83

4.5.1 Why this paper was written?

The medical facilities in the recent conflicts in Iraq and Afghanistan were relatively well developed. Towards the end of 2012, the UK-DMS changed its focus to undertaking roles in contingency operations. The Oxford Dictionary definition of a contingency is *'a future event or circumstance which is possible but cannot be predicted with certainty'* another definition more pertinent to the military is '*planning, reorganising and training so that we are ready to deploy wherever and whenever to react across the full spectrum of operations from peace support including humanitarian aid to warfighting* (140)'. I have deployed operationally at short notice three times with a small surgical team on a Maritime Platform termed Role 2 Afloat (141), to the Philippians in 2013 (Operation PATWIN), the coast of Libya in 2016 (MNTS 16) and in support of troops in Bahrain in 2013. This article describes the concept of Role 2 Afloat and explains the importance of human factors in a small team, working with limited resources on a contingency operation. A knowledge transfer paper was required as the Defence Medical Services had shifted to contingency operations and it was important that lessons learnt in previous conflicts around human factors were translated into this new arena.

4.5.2 What was known at the time of writing?

The composition of the Role 2 Afloat Team is described in Table 4.1. I have previously published a paper on the Anaesthesia and Critical Care requirements of Role 2 Afloat (141) but for the purposes of this thesis the Role 2 Afloat is a small surgical team that operates from either the Aircraft Carrier (currently HMS QUEEN ELIZABETH II) or a Royal Fleet Axillary Platform such as RFA MOUNTS BAY. The team is on a period of readiness (I was on 48 hours 'notice to move' at various points in my career) and can deploy to anywhere in the world and be ready to work operationally within 48 hours. The key differences to this team from others

previously described are the limited personnel and resources with a set kit list from *'the 370 module'* and in essence this team is set up to deal with two seriously wounded casualties at any one time. The situation now is that mindsets must change and there is no longer plentiful blood and operating theatre equipment and beds to hold patients and so clinical decision making must focus on limited kit and equipment. These decisions are borne out in this paper with human factors playing an important role and two typical cases are used to illustrate this. Human Factors differences from that previous found in Camp Bastion are discussed in Table 4.2.

Table 4.1. The composition of the Role 2 Afloat Team

- Consultant in Emergency Medicine
- Emergency Medicine Nurse 1
- Emergency Medicine Nurse 2
- Emergency Medicine Nurse 3*
- Consultant Anaesthetist 1
- Consultant Anaesthetist 2
- Consultant General Surgeon
- Consultant Orthopaedic Surgeon
- Operating Theatre Practitioner/Theatre Nurse 1
- Operating Theatre Practitioner 2
- Operating Theatre Practitioner 3
- Biomedical Scientist
- Radiographer
- Critical Care Nurse 1
- Critical Care Nurse 2
- Critical Care Nurse 3
- Medical Assistant*
- Medical and Dental Servicing Technician

*These personnel, along with a nominated physician, also form the Maritime In-Transit Care (MITC) team.

Table 4.2 Differences from Camp Bastion (large mature trauma system)

Significantly reduced number of personnel	There were 6 Consultant Anaesthetists when I deployed to Camp Bastion and 2 consultants covering the Critical Care. Reduced personnel will lead to every member of the team being 'on call' to receive casualties all the time and could lead to fatigue. A small team can only look after a small number of patients safely. This unit is designed to look after two seriously injured casualties and so once they have arrived the facility is effectively closed and could impact on operational capability. Team members may be asked to undertake roles that they did not usually perform in Camp Bastion but that are in the competency base (e.g. performing the primary survey) Personnel could potentially become isolated if they are the only member of the team in their field of expertise (i.e. there is only one orthopaedic surgeon)
Reduced equipment	There is no CT Scanner. This was vital in Camp Bastion to determine injuries sustained and is an integral part of complex trauma management in the UK. Clinicians need to manage the patient without the aid of CT. There is no RoTEM. This limits decision making on the blood products that are required once there is control of bleeding. The facility does not carry platelets as their shelf life is only 7 days. There are only so many operating trays with the equipment required to conduct Damage Control Surgery. This limits the length of time the unit can remain active without the opportunity for resources to be resupplied Operations may be limited to life, limb and sight saving surgery.
Decision making	Ethical decisions may need to be made in view of limited equipment. Evacuation of patients – where to transfer to and at what point in the treatment pathway Conducting a rapid sequence induction and ventilating a patient carries a significant burden for the team

4.5.3 What the paper added or contributed to the 'global' clinical community?

This paper was written at a time when the Defence Medical Services were moving from mature operations in Afghanistan into contingency operations throughout the world. It was important that those clinicians who would be deploying with the Defence Medical Services appreciated the difference in deploying to a very resource rich (personnel and equipment) location such as Afghanistan or Iraq and a resource poor deployment on for example a ship in the South Atlantic. Many of the ideas and mental models that were discussed and presented have now been taken on board by the three services (Royal Air Force, Royal Navy and British Army) on recent deployments, including to South Sudan in 2018 (91). An appreciation of the importance of human factors whist deployed on a contingency operation is extremely important and I was able to appreciate this first hand on deployments with the Role 2 Afloat team(141), a small surgical team deployed on a maritime platform.

4.5.4 Where are we now?

This article outlined the important human factors in a resource limited military maritime environment and used two case studies to describe the importance of human factors. Moving forward, the UK-DMS are now involved in several contingency operations and it is not expected that there will be the need for a mature trauma system as there was in Camp Bastion for the foreseeable future. This knowledge has been fed into the training system and formed a series of workshops to develop mental models prior to deployment. The Military Operational Surgical Training Course (94) has recently been relaunched with a new focus on contingencies.

Research and Knowledge Exchange

Graduate School

Form **RDPUB (ROUTE 1 AND 2)**

Manchester Metropolitan University

PhD BY PUBLISHED WORK (ROUTE 1/2): CONTRIBUTION TO PUBLICATIONS

This form is to accompany an application for registration for PhD where the PhD is by Published Work. A separate form should be completed for <u>each</u> publication that is submitted with the proposal and should accompany the RD1 form.

1. The Candidate

First Name(s):	Simon Jude	Preferred Title:	Dr
Surname:	Mercer		
MMU e-mail address:	simon.mercer@stu.mmu.ac.uk	Contact Number:	07970153168
Personal e-mail address:	simon.mercer2@nhs.net	Student ID Number:	19005767

2. Title of PhD Proposal

ADVANCES IN HUMAN FACTORS IN COMPLEX TRAUMA AND EMERGENCY ANAESTHESIA AND THEIR IMPLEMENTATION INTO MILITARY AND CIVILIAN TRAUMA SYSTEMS

3. Title of Research Output

Fadden S, Mercer SJ. Followership in Complex Trauma. Journal of Trauma 2019; 21: 6-13

4. Candidate's contribution to the research output

(State nature and approximate percentage contribution of each author)

S Mercer (85%) - inital idea for publication, literature review, 1st draft and subsequent drafts
S Fadden (15%), manuscipt revisions and subsequent drafts

5. Co author(s):

I confirm that the contribution indicated above is an accurate assessment of the contribution by the candidate to the research output named in section 3.

Name	Signature	Current e-mail address
S Fadden		sjf1612@aol.com

6. Statement by Director of Studies/Advisor

I confirm that I have read the above publication and am satisfied that the extent and nature of the candidate's contribution is as indicated in section 4 above.

Signature: _____ Date: _____

(Director of Studies/Advisor)

7. Signature of Faculty Research Degrees Administrator

Signature: _____ Date: _____

(Faculty Research Degrees Administrator)

Review Article

TRAUMA

Trauma
2019, Vol. 21(1) 6–13

DOI: 10.1177/1460408618757802
journals.sagepub.com/home/tra
SAGE

Followership in complex trauma

Sarah Fadden and Simon J Mercer

Abstract

Recent conflicts in Iraq and Afghanistan have highlighted the importance of human factors in complex trauma management. A reorganisation of trauma services in England has led to the creation of Major Trauma Centres and Major Trauma Collaboratives, with dedicated Trauma Teams. Much attention has been devoted to the role of team leader and leadership skills, with the human factor concept of followership largely overlooked. This article examines the importance of followership in the trauma team, scrutinising several different followership styles. Followership should be highlighted during trauma team training, promoting the practice of good followership to support the team leader and improve patient care.

Keywords

Followership, human factors, leadership, team work, trauma

Introduction

Human factors in healthcare in the United Kingdom have been highlighted by the recent acceptance of a National Quality Board concordat[1] by several UK bodies. One definition for human factors is *'enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture and organisation on human behaviour and abilities and application of that knowledge in clinical settings'*,[2] another is *'the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance'*.[3] Recommendations from seminal papers published at the start of the 21st century[4,5] were initially slow to be adopted until several prominent cases[6,7] demonstrated the catastrophic effect of a human factors breakdown. Reflection on recent conflicts in Iraq (OPERATION TELIC) and Afghanistan (OPERATION HERRICK) have highlighted the importance of human factors in the management of complex trauma,[8–10] which has also been considered in civilian practice.[11] Analysis of human factors and non-technical skills in different clinical subspecialties has led to the development of frameworks for anaesthetics,[12] surgery[13] and scrub practitioners,[14] with much of this work stemming from the key team resource management principles described by Gaba and Rall[15] (Table 1). These principles can be applied to the development of trauma teams that have evolved from the reorganisation of trauma services in England.[16]

The trauma team is a resource-rich unit of individuals from many sub-specialties (Table 2), which is activated according to pre-determined criteria based on the casualty's mechanism of injury, injuries sustained, anatomy and physiology (Table 3). Although there is no published framework for trauma team human factors, several of those already established for other specialties can easily be adapted. The anaesthetist's non-technical skills framework (ANTS)[12] has four separate behaviour categories, comprising task management, team working, situational awareness and decision-making (Table 4), all of which can be applied in the trauma resuscitation setting. When activated, the trauma team prepares to receive the patient (including allocating roles and setting up equipment), then co-ordinates activities and exchanges information once primary survey of the casualty is under way. Throughout, the team leader is responsible for maintaining situational awareness and ensuring robust decision-making, which culminates in a plan for ongoing management, usually at the end of the secondary survey.

Aintree University Hospital NHS Foundation Trust, Liverpool, UK

Corresponding author:
Simon J Mercer, Aintree University Hospitals NHS Foundation Trust, Longmoor Lane, Aintree, Liverpool L9 7AL, UK.
Email: simonjmercer@hotmail.com

Table 1. Key Team Resource Management Principles as outlined by Gaba and Rall.[15]

• Know the environment
• Anticipate and plan
• Call for help early
• Exercise leadership and followership
• Distribute the workload
• Mobilize all available resources
• Communicate effectively
• Use all available information
• Prevent and manage fixation errors
• Cross (double) check
• Use cognitive aids
• Re-evaluate repeatedly
• Use good teamwork
• Allocate attention wisely
• Set priorities dynamically

Table 2. Composition of a typical National Health Service (NHS) Major Trauma Centre Trauma Team.

Team member	Designated role/responsibility
Emergency Medicine Consultant	Team leader
Emergency Medicine Registrar	Primary survey
Anaesthetist	Airway management +/− central venous access
Orthopaedic Surgeon	Advice on orthopaedic and soft tissue injuries
General Surgeon	Advice on general trauma surgery
Operating Department Practitioner (ODP)	Assistant to the anaesthetist
Scribe	Recording of trauma bay activity
Emergency Department Nurse 1	Checking of blood products and administration via rapid infuser
Emergency Department Nurse 2	Peripheral venous access
Runner	Delivery of blood samples to, and collection of blood products from, the laboratory
Radiographer	Portable X-rays (chest, pelvis) +/− CT scans (all as required)

CT: computed tomography.

Table 3. Trauma team activation criteria (from King's College Hospital, Major Trauma Service: Information for Members of the Trauma Team).

1. Traumatic event and one of the following:
• Oxygen saturation <90%
• Systolic BP <90 mm Hg
• Respiratory rate <9 or > 29 breaths/minute
• GCS <14
2. Penetrating injury to
• Head
• Neck
• Chest
• Abdomen
• Pelvis
• All gunshot wounds
3. Fractures
• Open or depressed skull fractures
• Pelvic fracture
• Two or more proximal long bone fractures
• Flail chest
4. Traumatic amputation
5. Blast or crush injury
6 Major burns
• 10% total body surface area (but lower threshold in child or elderly)
• Combination of burns and trauma
7. Road traffic crash
• High speed crash (>30 mph) or pedestrian versus vehicle at >20 mph
• Separation of rider and bike
• Intrusion into passenger compartment
• Ejection from vehicle
• Death in same passenger compartment
• Bull's eyed windscreen
• 20 min extrication time
8. Falls
• Height of >3 m
• Paediatrics – consider the age and height of the child in relation to the height fallen
9. HEMS transfer
10. Drowning/submersion

BP: blood pressure; GCS: Glasgow Coma Scale; HEMS: Helicopter Emergency Medical Service.

Followership

One principle of team resource management that is often overlooked is followership, although it is fundamentally important to the trauma team. Followership describes a set of skills and behaviours that help to

Table 4. The anaesthetists' non-technical skills framework.[12]

Category	Element
Task management	Planning and preparing
	Prioritizing
	Providing and maintaining standards
	Identifying and utilizing resources
Team working	Coordinating activities with team members
	Exchanging information
	Using authority and assertiveness
	Assessing capabilities
	Supporting others
Situational awareness	Gathering information
	Recognizing and understanding
	Anticipating
Decision-making	Identifying options
	Balancing risks and selecting options
	Re-evaluating

improve team performance.[17] The term 'follower' itself often conjures up unfavourable images[18] and negative connotations,[19] resulting in a degree of stigmatisation.[20] This is in stark contrast to the term 'leader' which may be perceived as more dominant, and therefore a more prestigious and desirable role. There are several definitions of the word 'followership' in the literature but, simply put, it implies people having a shared vision of a common goal or future state, and what needs to be done to reach it.[21] It has also been described as a process in which subordinates recognise their responsibility to comply with the orders of leaders and carry out those orders appropriately and to the best of their ability or, in the absence of orders, determine and perform the actions that will facilitate the end objective.[22] It is possible to view leadership and followership as complementary, and two-way, rather than dichotomous endeavours. Ideally, these roles occupy a spectrum that represents the multidisciplinary, yet convergent, experiences and activities of an effective team. Describing the 'Courageous Follower', Chaleff defines followership as a discipline of supporting leaders and helping them to lead well. He makes the point that followership is not submission, *'but the wise and good care of leaders, done out of a sense of gratitude for their willingness to take on the responsibilities of leadership and a sense of hope and faith in their abilities and potential'*.[23] So, followership is '*the active engagement of followers in helping the group achieve its goals*'[24] and '*the ability to take direction well, to get in line behind a program, to be part of a team and to deliver on what is expected of you*'.[20] In the trauma setting, the physiological state of the patient can fluctuate greatly, necessitating rapid decision-making with regard to administration of blood products and transfer of the patient to the operating theatre, making support of the trauma team leader (TTL) by their followers essential.

Followership styles

An ideally functioning trauma team relies on good followership. It is important that organisations are aware of the different follower styles that have been described and that these are scrutinised during training serials, in order to enable individuals to learn how best to support the TTL and their colleagues. Several different followership styles have been described which could be applicable to the trauma team.

Robert Kelley

Kelley describes five different followership styles[25]:

- ***The 'Passive Followers' (or the sheep)*** *(1–2% of an organization)*: They lack initiative and rely on the leader to do all the thinking for them saying what the leader wants to hear even to the point of withholding information. They go along with whatever the leader decides, are quite passive and require constant supervision.
- ***The alienated follower*** *(15–25% of an organization)*: They have very negative attitudes, fighting against the team leader. They are thought of as hurt and angry towards the system with the individual lashing out whenever there is an opportunity.[26] They do not work in a team.
- ***The pragmatic follower*** *(25–25% of an organization)*: These followers are described as 'sitting on the fence' looking out for themselves and lack commitment, preserving the 'status quo'. They are also described as performing required tasks, but remain sensitive to internal politics and, consequently, do not take strong positions within the group.
- ***Conformist follower*** *(20–30% of an organization)*: These followers lack creative thinking are happy to take ordering and are 'yes people'. They are described as avoiding of perceived conflict, instead existing just under the radar.
- ***Exemplary followers*** perform well in every aspect; they actively engage with their leaders and their environment and exhibit independent, critical thinking. They support the team and the leader and go above and beyond what is required of them focusing on the goal by taking initiative.

Ira Chaleff

Chaleff describes the 'Courageous Follower'[27] formed along two axis; those that have courage to support the leader and those that have courage to challenge the leaders' behaviour or policies. There are four styles:

- **Implementer** – Described as dependable, considerate, providing a very high level of support, but are less willing to challenge.
- **Partner** – These followers fully support their leader but are also ready and willing to challenge, if necessary.
- **Individualist** – These followers tell their leader exactly what they think and how they feel. They are isolated and provide a low level of support to the leader, often challenging them.
- **Resource** – These followers do the bare minimum and although they are available to their leaders they are not committed to them and rarely challenge.

Barbara Kellerman

Kellerman aligns followers on one axis; the level of engagement and divides followers into five types along this continuum from feeling and doing absolutely nothing on the one end to being passionately committed and deeply involved on the other.[28]

- **Isolate –** Detached and do not care about the leader. They leave it up to others to make their decisions as they are uninterested and uninformed.
- **Bystander** - Disengaged and do not participate.
- **Participants -** These are some way engaged favouring their leaders, the groups and organizations of which they are members.
- **Activists -** They are eager, energetic and engaged, investing themselves in the process, working hard for the leader.
- **Diehards -** Truly devoted to the leader they are prepared to die if necessary for their cause, whether an individual, or an idea or both.

Followership in relation to the trauma team

A modern trauma team in a Major Trauma Centre (MTC) will be led by a Consultant, usually in Emergency Medicine. One definition of a leader is *'a person whose ideas and actions influence the thought and the behaviour of others',*[3] in a position to influence, inspire and direct in order to attain a desired objective. In terms of trauma, the aim is to receive, assess and stabilise a casualty and move them to the next most appropriate stage of their treatment pathway swiftly and safely. Healthcare professionals who deliver care to trauma patients have a responsibility to keep up-to-date with training in the skills they are required to perform.[29] Following activation of the trauma team, there will be a period of preparation of equipment and personnel.[30] Here, there is an opportunity to introduce team members by their name, role and competencies and brief the team based on the TTL's mental model of what they expect to happen. Once the team has assembled they must remain in the trauma bay until they are stood down by the TTL, reducing the chance that problems will get missed or tasks left unfinished.

The team must be proactive and make good use of the preparation time prior to the arrival of the casualty. Equipment is checked and drugs are drawn by the anaesthetist in the form of a pre-determined 'wetpack' of drugs, usually consisting of an induction drug (ketamine), muscle relaxant (often rocurionium), analgesic (fentanyl), antibiotics and tranexamic acid.[31] The organisation of these drugs is particularly useful in expediting the availability of the controlled drugs, the signing out of which requires two members of designated clinical staff. During this preparation phase, anticipated clinical tasks are discussed, including contingency plans for potential problems, such as which team member would perform an emergency cricothyroidotomy in the event that the patient has an airway that cannot be intubated conventionally. It is important to liaise with other hospital departments at this time, such as radiology, emergency theatres and blood bank, as their services may be required. Much of this clinical heads-up is now performed automatically, without specific direction from the TTL, and is considered to be one of the aspects of 'good followership' that enables the trauma team to function so efficiently. For example, MTCs have a process termed 'code red' to enable blood and blood products to be available prior to the casualty arriving, based on information from the pre-hospital team.[32] A runner is sent to the laboratory to collect a 'shock pack' of blood products that are delivered a box with a timer. It is vital that the TTL is made aware if products are not required and can be returned to the fridge within 30 min of having been issued, thereby maintaining their viability.

When the casualty arrives at the trauma bay, a five-second check, similar to that described on the European Trauma Course,[33,34] is prompted by the TTL to confirm that the patient is alive, does not have visible catastrophic haemorrhage and has a patent airway. Once this has been established, it is important that all team members listen in silence to the handover from the pre-hospital team, which is relayed using the mnemonic age, time of injury, mechanism of injury, injuries

sustained, signs and symptoms and treatment given (AT-MIST). By listening to, and understanding, the handover everyone in the team should have a shared mental model of the case, enabling them to work effectively both on individual tasks and in support of the wider team activities. Thereafter, the TTL has the role of ensuring that members of the team continue to work together synergistically, by providing regular situational updates (Sit-Reps). Once the patient has been transferred to the trauma trolley, the primary survey is conducted using a horizontal approach[35] (many components at the same time) in the catastrophic haemorrhage, airway/C-spine, breathing, circulation (<C>ABC)[36] format. This approach facilitates rapid, almost concurrent, assessment and treatment of the casualty, which is co-ordinated by the TTL and, at its optimum, might be analogised to a well-drilled Formula One pit stop.[11] To enable effective communication, general noise levels must be kept to a minimum and limited to the transfer of information between the TTL and trauma team. Communication is also facilitated by a senior member of the team taking on the role of the scribe and documenting the full sequence of events. Many of these processes occur automatically, and without the need for micromanagement by the TTL, thereby demonstrating good followership. An example of initial actions for a patient involved in a motor vehicle accident is shown in Table 5.

Throughout, as far as possible, the TTL should adopt a 'hands off' role, as they are responsible for maintaining the overall situational awareness of the team. This TTL oversight allows other members of the team to concentrate on their own roles, whilst also preventing fixation errors, where a single problem is focused on to the detriment of the casualty as a whole.[37] Once the secondary survey has been completed, it is important that the team are then able to support the TTL with further decision-making. The Defence Medical Services (DMS) have developed the concept of the Command Huddle,[9] whereby senior members of the team collaborate in deciding the most appropriate next stage of a casualty's treatment. The potential patient pathway is outlined in Figure 1:

- Is treatment futile? (not usually a considered option)
- If treatment is to continue then should the patient be transferred directly to
  - Computed tomography (CT) scanner (most favourable option)
  - Operating theatre
  - Critical care (if CT and surgery have already occurred at a Trauma Unit and patient physiology is not impaired)
  - Trauma ward
  - Another facility with specialist care

Table 5. Initial management tasks performed by the trauma team when receiving a casualty from a major motor vehicle accident.

Primary survey <C> ABC
Cervical spine immobilisation (if not already performed)
Pelvic binder secured
Peripheral intravenous access established
Blood samples taken for
• Thromboelastometry (RoTEM®)
• Full blood count
• Group and save
• Urea and electrolytes
• Venous blood gas
• INR (if patient takes warfarin)
Chest and pelvic digital X-rays (reported by consultant radiologist and viewed by trauma team clinicians)
Rapid sequence induction (by anaesthetist and ODP if required)
• Ketamine 1–2 mg/kg (+/− Fentanyl 1–3 μg/kg)
• Rocuronium 1 mg/kg
Insertion of a trauma line if indicated (usually in the Subclavian Vein)
Connection of rapid infusion device and commencement of haemostatic resuscitation
Additional drugs administered
• Ketamine (for sedation)
• Fentanyl
• Neuromuscular blocking drug (Rocuronium)
• Tranexamic acid 1 g (15 mg/kg)
• Tetanus vaccination
• Antibiotics
• Calcium chloride (10 ml of 10%) (monitor ionised calcium)
Commencement of activing warning (using BairHugger™)

<C>ABC: catastrophic haemorrhage, airway/C-spine, breathing, circulation; ODP: operating department practitioner.

- If immediate transfer to the operating theatre is required, then which theatre has been allocated in the hospital? What equipment is required and which body cavity is to be opened first?
- Does the patient require a rapid sequence induction of anaesthesia (RSI) prior to theatre and, if so, in which location is it safest to perform?

An organisation requires far more good followers to meet its objectives than it does leaders.[38] However, in addition to demonstrating attributes such as a strong work ethic, competence, honesty, courage, discretion, loyalty and ego management,[20] good followers also

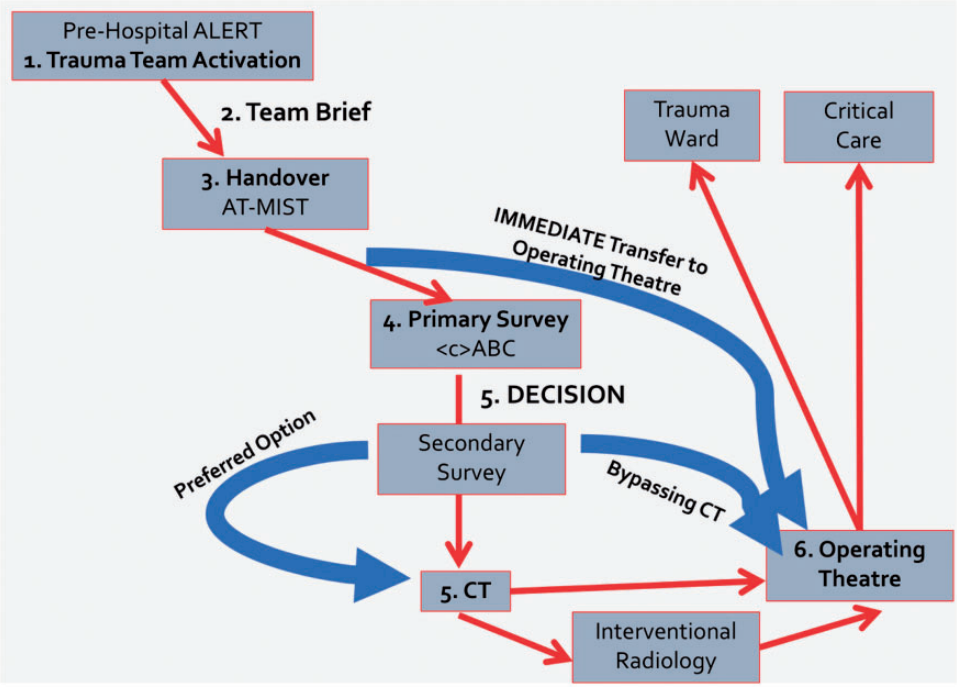


Figure 1. The patient pathway in a Major Trauma Centre. Unless a patient needs to be transferred urgently to theatre following the handover then a decision is usually made during the Command Huddle (point 5) where senior members of the team support the TTL. There are five decision points listed: 1. Trauma Team Activation, 2. Team Brief, 3. Handover, 4. Primary Survey and 5. a decision point after the primary survey as to the most appropriate next stage of treatment.
ABC: airway/C-spine, breathing, circulation; AT-MIST: age, time of injury, mechanism of injury, injuries sustained, signs and symptoms and treatment given; CT: computed tomography.

engage actively in their endeavours and think for themselves.[25,27,39] In the trauma team, this may manifest in challenging the TTL, when appropriate. Complex trauma can present multiple differential diagnoses and treatment priorities, and failure on the part of a team worker to challenge an erroneous TTL decision may lead to adverse outcomes.[40,41] Kelley describes a crucial aspect of followership as '*the ability to make ethical and legal judgments, to take proactive steps to promote ethical and legal activities and then to stand up against unethical and illegal decisions*'.[42] Erroneous decisions can remain unchallenged, not because of a failure to notice that the decision is wrong, but because of reluctance to challenge the leader,[43] and it is important to address why a member of the trauma team might feel this – perhaps, in part, due to the hierarchical nature of the medical profession.[44] So-called 'compliant followers' do not challenge,[45] whereas 'responsible followers' have the interpersonal skills to challenge authority and decision-making in a way that will not create a defensive or risk-averse culture.[45]

Conclusions

The trauma team in a MTC is a resource-rich unit made up of a multi-disciplinary team under the direction of a TTL. In effect, everyone on the team is a follower and so should be encouraged to display the characteristics ascribed to a 'good follower'. This will enable the TTL, with the team, to assess and stabilize a casualty rapidly, and to determine effectively the next appropriate intervention. Those in senior positions should be encouraged to identify differing followership styles and aim to use training sessions (particularly with fully immersive simulation) to explore the values individuals bring to the trauma team in order to encourage exemplary followership.

Acknowledgements

We would like to thank Dr Clinton Jones for his advice in preparing the manuscript.

Authors' contributions

Simon Mercer – Initial idea to write the paper, researched material for paper, wrote first draft and subsequent revisions. Sarah Fadden – Researched material to be included in the paper, revised and added to manuscript several times.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Trial registration

This is an opinion article and no research was involved on human participant or animals.

Informed consent

This was not required as there was no research.

Ethical approval

Ethical approval was not sought for this article as it is a review of Followership in trauma and does not involve patients.

Guarantor

SM.

Provenance and peer review

Not commissioned, externally peer reviewed.

ORCID iD

Simon J Mercer http://orcid.org/0000-0001-9229-2132

References

1. NHS England. Human factors in healthcare – a concordat from the national quality board. 2013, www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf (accessed 20 June 2016).
2. Catchpole KR, Dale TJ, Hirst DG, et al. A multicenter trial of aviation-style training for surgical teams. *J Patient Saf* 2010; 6: 180–186.
3. Flin R, O'Connor P and Crichton M. *Safety at the sharp end*. Cornwall: Ashgate, 2008.
4. Kohn LT, Corrigan JM and Donaldson MS. *To err is human: building a safer health system*. Washington: National Academies Press, 2000.
5. Department of Health. *An organisation with a memory*. The Stationary Office, London, 2000, pp.VII–XI.
6. Bromiley M. Have you ever made a mistake? *R Coll Anaesth Bull* 2008; 48: 2442–2445.
7. Sheriffdom of Glasgow and Strathkelvin under the fatal accidents and sudden deaths (Scotland) ACT 1976. Determination of Sheriff Linda Margaret Ruxton in fatal accident inquiry into the death of Gordon Ewing, www.scotcourts.gov.uk/opinions/2010FAI15.html (accessed 20 June 2016).
8. Mercer S, Arul GS and Pugh HEJ. Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma. *J R Army Med Corps* 2014; 160: 105–108.
9. Arul GS, Pugh H, Mercer SJ, et al. Optimising communication in the damage control resuscitation-damage control surgery sequence in major trauma management. *J R Army Med Corps* 2012; 158: 82–84.
10. Midwinter MJ, Mercer S, Lambert AW, et al. Making difficult decisions in major military trauma: a crew resource management perspective. *J R Army Med Corps* 2011; 157: S299–S304.
11. Mercer S, Park C and Tarmey NT. Human factors in complex trauma. *BJA Educ* 2015; 15: 231–236.
12. Fletcher G. Anaesthetists' non-technical skills (ANTS): evaluation of a behavioural marker system dagger. *Br J Anaesth* 2003; 90: 580–588.
13. Yule S, Flin R, Paterson-Brown S, et al. Non-technical skills for surgeons in the operating room: a review of the literature. *Surgery* 2006; 139: 140–149.
14. Mitchell L and Flin R. Non-technical skills of the operating theatre scrub nurse: literature review. *J Adv Nurs* 2008; 63: 15–24.
15. Gaba DM and Rall M. Human performance and patient safety. In: Miller RD (ed.) *Miller's anesthesia*. Philadelphia: Elsevier Churchill Livingstone, pp. 3021–3072.
16. McCullough AL, Haycock JC, Forward DP, et al. II. Major trauma networks in England. *Br J Anaesth* 2014; 113: 202–206.
17. Whitlock J. The value of active followership. *J Nurs Manag* 2013; 20: 20–23.
18. Alcorn DS. Dynamic followership: empowerment at work. *Manag Q* 1992; 33: 9–13.
19. Bligh MC and Kohles JC. From radial to mainstream? How followercentric approaches inform leadership. *Z Psychol* 2012; 220: 205–209.
20. McCallum JS. Followership: the other side of leadership. *Ivey Business Journal Online* 2013, http://search.proquest.com/docview/1441622033?accountid=50025 (accessed 20 June 2016).
21. Schiemann WA. Aligning people. *Leader Excel* 2007; 24: 20.
22. Townsend P and Gebhartd JE. For service to work right, skilled leaders need skills in 'followership'. *Manag Serv Qual* 1997; 7: 136–140.
23. Chaleff I. Creating new ways of followership. In: Riggio RE, Chaleff I and Lipman-Blumen J (eds) *The art of followership: how great followers create great leaders and organisations*. San Francisco: Wiley, pp. 67–88.
24. Hogg MA. Social identity processes and the empowerment of followers. In: Riggio RE, Chaleff I and Lipman-Blumen J (eds) *The art of followership how great followers create great leaders and organisations*. San Francisco: Wiley, pp. 267–276.
25. Kelley RE. *The power of followership*. New York: Doubleday, 1992.
26. Colangelo AJ. Followership: leadership styles. Doctoral dissertation, The University of Oklahoma, 2000. *Dissert Abstr Int* 2000; 61: 1934.
27. Chaleff I. *The courageous follower*. 3rd ed. San Francisco: Berrett-Koehler, 2009.
28. Kellerman B. *Followership: how followers are creating change and changing leaders*. Boston: Harper Business, 2008.
29. National Institute for Health and Clinical Excellence. *Major trauma: assessment and initial management*. London: NICE, 2016.
30. Horne S and Smith JE. Preparation of the resuscitation room and patient reception. *J R Army Med Corps* 2011; 157: S267–S272.

4.6 Followership in Complex Trauma. Fadden S, MERCER SJ. *Trauma* 2019; 21: 6-13

4.6.1 Why this paper was written?

Followership is often over looked at as a non-technical skill in favour of leadership. An example of this is that an www.amazon.co.uk search of leadership books produced over 100,000 choices compared to just 269 books on followership[2]. There is perhaps a degree of stigmatism (142) and negative connotations (143) when compared with leadership, but followership is vital and underpins the functioning of the complex trauma team. This article summarises several current followership theories and outlines different types of followers. This information is important when trauma teams are constructed or where individuals look at their own behaviours as part of the trauma team. A knowledge translation paper was required as this field of human factors is often neglected, and it was important that all members of the trauma team were aware of the vital roles that they played by appreciating the importance of good followership.

4.6.2 What was known at the time of writing?

Followership describes a set of skills and behaviours that help to improve team performance (144). It is also described as people having a shared vision, of a common goal or future state, and what needs to be done to reach it (46). Followership is also a process in which team members recognise their responsibility to comply with the orders of leaders and carry out those orders appropriately and to the best of their ability or, in the absence of orders, determine and perform the actions that will facilitate the end objective (145). Chaleff describes followership as 'the active engagement of followers in helping the group achieve its goals'

[2] Amazon.co.uk search performed on 21 January 2019

(146) and in his book, the 'Courageous Follower' (147) describes four styles of followership which are outlined in the paper

- Implementer
- Partner
- Individualist
- Resource

Robert Kelley's describes five different styles of followership (148)

- The 'Passive Followers' (or the sheep)
- The alienated follower
- The pragmatic follower
- Conformist follower
- Exemplary followers

Barbara Kellerman also describes five different types of followership (149).

- Isolate
- Bystander
- Participants
- Activists
- Diehards

It is important for those who train and develop complex trauma teams to be aware of the different styles of followership that exist to allow teams to practice and be aware of where they fit into them.

4.6.3 What the paper added or contributed to the 'global' clinical community?

This article outlines a trauma call, but this time focuses of the elements of followership that ensure its smooth running. In many respects a follower is someone who is proactive, a team member who gets on with what needs doing without always being instructed to do so by the trauma team leader. They also work to support and assist the trauma team leader at every

opportunity with the mindset that everyone is working towards the same goal; the patient. Specific examples of how this works in clinical practice are described below in Table 4.3

Table 4.3 Specific examples of followership within the trauma team.

Preparing to receive a patient	Members of the trauma team set about to prepare for the arrival of the patient this period of time whilst the patient is on route to the hospital is vital in terms of smooth progression of the trauma team. This process involves preparing specific equipment and drawing up drugs that will be required Communicating with other agencies in the hospital, e.g. the operating theatre, radiology and transfusion Discussing contingency planning amongst the team
Handover	Listening to the AT-MIST handover so that all team members are on the 'same page' and can adhere to the mental model of the trauma team leader. Team members will not be in a position to demonstrate good followership if they are not clear on the circumstances or mechanism of injury.
Primary Survey	Ensuring good communication with the trauma team leader so that they are aware of the initial physiology and examination Allowing the primary survey to be conducted rapidly with a horizontal approach. The trauma team lead has the role of piecing together all the clues and this gathering of information is the first stage of situational awareness. This is then shared with the rest of the trauma team during a situational update (or Sit-Rep in the military)
Command Huddle	Advising on the next stage of patient treatment The command huddle is an important vehicle to enable shared robust decision making and ensuring that the patient is moved to the right area at the right time. Members of the command huddle (14) bring their strengths and expertise to the table and guide the trauma team leader on the best course of action.

Kelley described a crucial aspect of followership as *'the ability to make ethical and legal judgments, to take proactive steps to promote ethical and legal activities and then to stand up against unethical and illegal decisions'* (150). This highlights the need to create a culture where team members are comfortable with challenging the trauma team leader if necessary. Erroneous decisions can remain unchallenged, not because of a failure to notice that the decision is wrong, but because of reluctance to challenge the leader (68). So-called 'compliant followers' do not challenge (151), whereas 'responsible followers' have the interpersonal skills to challenge authority and decision-making in a way that will not create a defensive or risk-averse culture (151). Our previous work on junior members challenging senior members of the team (70) ties in with what has been described around followership and we look to highlight this in trauma team training at our institution (8).

4.6.4 Where are we now?

This paper outlines current theories on followership and describes these principles in the context of the complex trauma team. It is clear that the function and success of the trauma team relies on the followership of the team members to complement the trauma team leader. Training the trauma teams should focus on followership and create a culture that allows participation and challenging of erroneous decisions.

Section 5

Contribution of the Thesis to Knowledge and Implications of the Thesis

5.1 Contribution of the Thesis to Knowledge

This thesis describes original research investigating the perceived barriers to junior anaesthetists challenging their consultants when they are concerned that an error has occurred. This knowledge has led to an enhanced appreciation of what worries or indeed motivates junior colleagues to challenge their seniors. A previous lack of challenging in high profile cases has led to serious patient safety issues [27] when ultimately the correct challenge could have prevented mistakes from occurring. This additional knowledge is now incorporated into regional teaching in the Mersey Anaesthesia rotation for novice trainees with the intention to ensure they are comfortable with challenging from an early stage of their career [154] and raised the profile of challenging in the Anaesthesia community. This is demonstrated by the original knowledge paper [70] now being cited 28 times in the medical literature.

'The Trauma WHO' [14], a tool to improve communication during damage control resuscitation [64] has been described and then subsequently tested and refined in an operational military field hospital [42]. This process consists of an initial 'command huddle' where early decisions are made by senior members of the trauma team, a 'snap brief' prior to surgery commencing which ensures all members of the team are 'on the same page' and regular 'sit-reps' which are effectively situational updates occurring throughout the surgery. The pneumonic STACK [86] has been adapted to provide a rapid exchange of information between the surgical and anaesthetic teams to ultimately determine the length of time it is permitted to remain on the operating table based on the patient's physiology; particularly acidosis, hypothermia and coagulopathy.

Finally, this thesis concentrates on the management of the anticipated difficult airway, particularly in penetrating trauma. This topic may at first appear to concern a technical skill, however the expert and successful management of complex airway issues require exceptional human factors [96] and patient harm has occurred where human factors have been suboptimal

[139]. This thesis has described original research in the creation of guidelines for the management of penetrating airway trauma [113] and then developed this knowledge further by means of a systematic literature review [95] to create a series of flow diagrams to encourage anaesthetists working in the frontline to develop their own mental models to deal with this rare but potentially hazardous condition.

5.2 Implication of the Thesis

The aim of this thesis was to describe recent advances in human factors in complex trauma and emergency anaesthesia with a view to informing all members of the multi-disciplinary trauma team working in the frontline in major trauma centres in England [6]. As an active consultant trauma anaesthetist, I am passionate that my patients receive the highest quality of care from point of wounding to rehabilitation and this requires timely robust decisions to be made and executed by the team to allow the patient to move safely to the next stage of their pathway. Analysis of trauma care in the military setting [5] and more recently the reorganised regional civilian trauma centres [2] has led to discussions that noticeable improvements are not just due to advances in surgical or anaesthetic techniques but to the appreciation of the role of human factors amongst members of the trauma team [86].

The original knowledge created, synthesised and described in this thesis concerning human factors in complex trauma and emergency anaesthesia has now been transferred and exchanged into the frontline. The implications of this thesis are therefore in the impact that this additional knowledge and knowledge translation has had in the frontline. During the recent COVID-19 pandemic, I have personally witnessed two episodes of patient care that have directly benefited resulting from training the team using the principles outlined in this thesis. These are described as follows

a) A young lady (early twenties) was admitted as a Code Red Trauma Call [63] following self-inflicted penetrating trauma to the neck with the stem of a broken wine glass. This case was managed using the principles described in the thesis on the importance of

human factors when managing the anticipated difficult airway [96] and used a mental model developed in the systematic review [95]. Placement of the endotracheal tube was confirmed to be in the correct place under direct vision with a fiberoptic laryngoscope and potentially catastrophic surgical emphysema was avoided.

b) A middle-aged man (mid-fifties) was admitted as a Code Red Trauma Call [63] having been run over by a train. He suffered life changing injuries to his left arm and leg and arrived at the trauma centre hypothermic, acidotic and coagulopathic. The principles of 'The Trauma WHO' [14] were used throughout this case. A 'command huddle' performed at the end of the primary survey [63] determined that this patient required immediate surgery to stop catastrophic haemorrhage and he was transferred to the operating theatre within 5 minutes. Following a 'snap brief' involving three separate surgical teams, surgery commenced with regular 'sit-reps' every 10-15 minutes resulting in a total operating time of eight-five minutes. The patient left the operating theatre and was then transferred via CT-scanner to critical care with normal physiology and coagulation. This was a very successful execution of damage control resuscitation [64]

Finally, the principles of human factors in complex trauma are firmly embedded into the Defence Medical Services. Knowledge translation papers have described the importance in a mature field hospital [86] and also within a small team on a contingency operation [141] in addition to the importance of followership amongst the team [49]. These are discussed in small group workshops and practiced using high fidelity simulation on the Military Operational Surgical Training Course [94] to ensure that all members of the team are prepared to deal with complex trauma patients should the need arise. Recent operations in support of the United Nations Mission in South Sudan [155] have reported the value of using the principles of 'The Trauma WHO' [14] successfully in another military arena.

Conclusion

I am passionate about the importance of human factors in healthcare and the goal of my work has been to implement human factors into military and civilian trauma teams to improve patient outcome. I have described how outcomes in military (5) and civilian (2) practice have improved over the last 10 years; and I strongly believe that this is not just down to advances in surgical and anaesthetic management but due to improvements in human factors and this opinion is shared by others (92). I have established myself as an invited national speaker and reviewer in the peer review process for several international journals including the *British Journal of Anaesthesia*. I continue to publish in the field of human factors and my publications are listed in chronological order in Appendix 1.

On pages 8-9, I stated that the aim of this thesis was to demonstrate that I have a systematic acquisition and understanding of a substantial body of knowledge and am at the forefront of an area of professional practice; human factors in complex trauma and emergency anaesthesia. This thesis has described and demonstrated some of the work that I have undertaken to generate knowledge through original research, by synthesising knowledge through systematic review and finally by the translation of knowledge through the production of expert articles. This statement was made in cognisance of the statement by the QAA (2011) Doctoral Degree Characteristics that Doctoral degrees are awarded to students who have demonstrated:

- the creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication
- a systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice
- the general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems
- a detailed understanding of applicable techniques for research and advanced academic enquiry.

The original research that was described in Section 2 centred around 3 different sub-topics

- The barriers to challenging seniors or to 'Speak Up'
- The testing and implementation of a communication tool in complex trauma – 'The Trauma WHO'
- Reviewing potential guidelines for the management of the airway in trauma

The systematic reviews in Section 3 explored further the management of the airway in complex trauma and suggested specific mental models for anaesthetists working on 'the shop floor' when presented with a patient with blunt or penetrating trauma to the airway or severe burns. In the second systematic review human factors were explained in the context of several recent national audits from the Royal College of Anaesthetists.

In Section 4, I specifically selected five articles to describe the importance of human factors in different clinical situations ranging from a mature field hospital, a civilian trauma centre and a small team deployed at sea with limited resources.

All the papers I have presented, I feel, demonstrate the achievement of the above criteria for a Doctoral Degree via Publication (Route 2) and demonstrated that I have a systematic acquisition and understanding of a substantial body of knowledge and am at the forefront of an area of professional practice. I have also summarised the range of research skills in terms of data collection, data analysis, knowledge synthesis and knowledge translation that these papers encompass. In my role as Director of Medical Education at Liverpool University Hospital NHS Foundation Trust I now use this knowledge to train trauma teams using high-fidelity simulation and have noticed improvements in our own results, particularly in the rapid progress of patients to CT Scan and the operating theatre when indicated. This is demonstrated in our routine submissions of trauma data to the Trauma Audit and Research Network.

I have described in each section *'where we are now'* following each publication. In terms of challenging seniors there has been further work following on from my study looking at the importance of challenging on the Intensive Care Unit (152) and for other member of the team in the Operating Theatre (78). There has also been further work around challenging behaviour in novice anaesthetists (153). I have developed several high fidelity simulation scenarios that are part of the Emergencies in Anaesthesia Course (154) undertaken by all 1st year anaesthetic trainees in my region and these are mapped to the curriculum of the Royal College of Anaesthetists. I intend to publish the effectiveness of these scenarios in the future.

The 'Trauma WHO' has been adopted universally in the UK-Defence Medical Services, but only by several centres in England. This has been where there are champions and usually where there is a Military contingent of clinicians. The articles published on this topic have been cited in the medical literature but in future I would try to involve more active marketing of this concept using social media in addition to talking at national meetings. Often new concepts such as the 'Trauma WHO' are slow to be adopted and when imposed on clinicians are often resented as I have witnessed myself with the blanket introduction of WHO Checklist (103). Further evidence for the effectiveness of the 'Trauma WHO' could be achieved by organising a multi-centre observational study and comparing the mortality for matched trauma patients in units that have implemented the 'Trauma WHO' with those that do not yet use it. This future research could persuade others to adopt a safety checklist that my teams find very effective.

Patient safety is now high on the agenda with the recent launch of the NHS Patient Safety Strategy(155) which covers three strategic aims:

- Improving understanding of safety by drawing intelligence from multiple sources of patient safety information
- Equipping patients, staff and partners with the skills and opportunities to improve patient safety throughout the whole system
- Designing and supporting programmes that deliver effective and sustainable change in the most important areas

I will continue to engage with this renewed focus on patient safety and human factors in the NHS and continue to champion the importance of human factors in complex trauma and emergency anaesthesia.

References

1. Vulliamy P, Faulkner M, Kirkwood G, et al. Temporal and geographic patterns of stab injuries in young people: a retrospective cohort study from a UK major trauma centre. *BMJ Open* 2018; **8**: e023114–6.

2. Moran CG, Lecky F, Bouamra O, et al. Changing the System - Major Trauma Patients and Their Outcomes in the NHS (England) 2008–17. *EClinicalMedicine* 2018; **2-3**: 13-21

3. National Confidential Enquiry into Patient Outcome and Death (2007) Trauma—Who Cares? London NCEPOD Available from http://www.ncepod.org.uk/2007report2/Downloads/SIP_report.pdf (accessed 22 June 2019)

4. Mercer SJ, Tarmey NT, Woolley T, et al. Haemorrhage and coagulopathy in the Defence Medical Services. *Anaesthesia* 2012; **68**: 49–60.

5. Penn-Barwell JG, Roberts SAG, Midwinter MJ, et al. Improved survival in UK combat casualties from Iraq and Afghanistan. *Journal of Trauma and Acute Care Surgery*. 2015; **78**: 1014-1020.

6. McCullough AL, Haycock JC, Forward DP, et al. Early management of the severely injured major trauma patient. *British Journal of Anaesthesia*. 2014; 18; **113**: 234–41.

7. Thies K, Gwinnutt C, Driscoll P, et al. The European Trauma Course—from concept to course. *Resuscitation* 2007; **74**: 135–41.

8. Mercer SJ. Using full immersive simulation to prepare trauma teams to work in a major trauma centre. *Trauma* 2017; **19**: 277–85.

9. Mercer SJ. Training and Revalidation in Defence Anaesthesia. *Bulletin of the Royal College of Anaesthetists*. 2013; **80**: 16–8.

10. Jones CL, Mercer SJ, Mahoney PF. Shaping military training in the era of contingency and revalidation. *Bulletin of the Royal College of Anaesthetists*. 2016; **97**: 41–3.

11. Ramasamy A, Hinsley DE, Edwards DS, et al. Skill sets and competencies for the modern military surgeon: Lessons from UK military operations in Southern Afghanistan. *Injury* 2010; **41**: 453–9.

12. Arora S, Sevdalis N. HOSPEX and concepts of simulation. *Journal of the Royal Army Medical Corps* 2008; **154**: 202.

13. Mercer SJ, Whittle C, Siggers B, et al. Simulation, Human Factors and Defence Anaesthesia. *Journal of the Royal Army Medical Corps* 2010; **156(S1)**: 365–9.

14. Arul GS, Pugh H, Mercer SJ, Midwinter MJ. Optimising Communication in the Damage Control Resuscitation-Damage Control Surgery Sequence in Major Trauma Management. *Journal of the Royal Army Medical Corps* 2012; **158**: 82–4.

15. Midwinter MJ, Mercer S, Lambert AW, et al. Making Difficult Decisions in Major Military Trauma: A Crew Resource Management Perspective. *Journal of the Royal Army Medical Corps* 2011; **157(S1**): S299–304.

16. Catchpole KR, Dale TJ, Hirst DG, et al. A multicenter trial of aviation-style training for surgical teams. *Journal of Patient Safety* 2010; **6**: 180–6.

17. Flin R, O'Connor P, Crichton M. Safety at the Sharp End: A Guide to Non-Technical Skills. Ashgate 2008:1.

18. Moneypenny MJ. When are 'human factors' not 'human factors' in can't intubate can't oxygenate scenarios? When they are "human" factors. *British Journal of Anaesthesia*. 2017;*118*: 469–9.

19. Health and Safety Executive. Reducing Error and Influencing Behaviour. 1989. Available at: http://www.hse.gov.uk/pUbns/priced/hsg48.pdf (accessed 22 June 2019)

20. Helmreich RL. On error management: lessons from aviation. *British Medical Journal* 2000; **320**: 781–5.

21. Helmreich RL, Davies JM. Anaesthetic simulation and lessons to be learned from aviation. *Canadian Journal of Anaesthesia*. 1997; **44**: 907–12.

22. Kohn LT, Corrigan JM, Donaldson MS, eds. To err is 23 human: building a safer health system, National Academies Press, Washington, 2000.

23. Department of Health. An Organisation with a Memory. The Stationary Office, London. 2000: VII–XI.

24. Feinmann J. Why sorry doesn't need to be the hardest word. *British Medical Journal* 2011; 342: d3258

25. Cook TM, Woodall N, Frerk C, on behalf of the Fourth National Audit Project. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. *British Journal of Anaesthesia.* 2011; **106**: 617–31.

26. Toft B. External Inquiry into the Adverse Incident that Occurred at Queen's Medical Centre, Nottingham, 4th January 2001. Available at: https://www.who.int/patientsafety/news/Queens%20Medical%20Centre%20report%20(Toft).pdf (accessed 22 June 2019)

27. Dyer O. Doctors suspended for removing wrong kidney. *British Medical Journal* 2004; **382**: 246.

28. Bromiley M. Have you ever made a mistake? *Bulletin of the Royal College of Anaesthetists* 2008; **48**: 2442–5.

29. Henderson JJ, Popat MT, Latto IP, et al. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004; **59**: 675–94.

30. NHS England. Human Factors in Healthcare - *A Concordat from the National Quality Board.* Available at: https://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf (accessed 22 June 2019)

31. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Executive Summary. 2013. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/279124/0947.pdf (accessed 22 June 2019)

32. Gaba DM. Crisis resource management and teamwork training in anaesthesia. *British Journal of Anaesthesia* 2010;**105**: 3–6.

33. Gaba DM, Rall M. Human Performance and Patient Safety. In: Miller RD, editor. Miller´s Anesthesia. Philadelphia: Elsevier Churchill Livingstone. 2005: 3021–72.

34. Fletcher G, Flin R, McGeorge P, et al. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *British Journal of Anaesthesia* 2003; **90**: 580–8.

35. Flin R, Yule S. Advances in Patient Safety: Non-Technical Skills in Surgery. *Surgeons News* 2005; 4: 83–5.

36. Mitchell L, Flin R. Non-technical skills of the operating theatre scrub nurse: literature review. *Journal of Advanced Nursing* 2008; **63**: 15–24.

37. Carthey J. Behavioural markers of surgical excellence. *Safety Science* 2003; **41**: 409–25.

38. Bion JF, Heffner JE. Challenges in the care of the acutely ill. *The Lancet* 2004; **363**: 970–7.

39. Salas E, Burke CS Stagl KC. Developing Teams and Team Leaders: Strategies and Principles. In Day DV, Zaccaro SJ, Halpin SM (Eds.), *Series in applied psychology. Leader development for transforming organizations: Growing leaders for tomorrow*. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers. 2004; 325-355

40. Katzenbach JR, Smith DK. *The wisdom of teams: Creating the high-performance organization*. 1993 New York: Harper Business.

41. Gawande A, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery*. 2003; **133**: 614–21.

42. Arul GS, Pugh H, Mercer SJ, Midwinter MJ. Human factors in decision making in major trauma in Camp Bastion, Afghanistan. *Annals of The Royal College of Surgeons of England* 2015; **97**: 262–8.

43. Endsley MR. Toward a theory of situation awareness in dynamic systems. Human Factors: *The Journal of the Human Factors and Ergonomics Society*.1995; **37**: 32–64.

44. Gaba DM, Howard SK, Small SD. Situation awareness in anesthesiology. *Human Factors* 1995; **37** :20–31.

45. Hogg MA. Social Identity Processes and the Empowerment of Followers. In: Riggio RE, Chaleff I, Lipman-Blumen J, editors. The Art of Followership How Great Followers Create Great Leaders and Organisations. Wiley; 2008: 267–76.

46. Schiemann WA. Aligning People. *Leadership Excellence* 2007; **24**: 20.

47. Bjugstad K, Thach EC, Thompson KJ, et al. A fresh look at followership: A model for matching followership and leadership styles. *Journal of Behavioral and Applied Management* 2006; **7**: 304–19

48. Rost J. Leadership for the twenty-first century. Prague: Westport; 1993.

49. Fadden S, Mercer SJ. Followership in Complex Trauma. *Trauma* 2019; **21**: 6-13

50. Murray CJL, Vos T, Lozano, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*. 2012; **380**: 2197–223.

51. Public Health England. Chapter 2: major causes of death and how they have changed. 2017. Available at: https://www.gov.uk/government/publications/health-profile-for-england/chapter-2-major-causes-of-death-and-how-they-have-changed (accessed 22 June 2019)

52. Baker SP, O'neill B, Haddon WJ, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *Journal of trauma and Acute Care Surgery* 1974; 14: 187.

53. Palmer C. Major trauma and the injury severity score - where should we set the bar? *Annual Proceedings. Association for the Advancement of Automotive Medicine* 2007; **51**: 13-29.

54. Stanworth SJ, Davenport R, Curry N, et al. Mortality from trauma haemorrhage and opportunities for improvement in transfusion practice. *British Journal of Surgery* 2016; **103**: 357–65.

55. Martin M, Oh J, Currier H, et al. An analysis of in-hospital deaths at a modern combat support hospital. *Journal of trauma and Acute Care Surgery* 2009; 66: S51–S61.

56. National Audit Office. Major Trauma Care in England. 2010 Available at: https://www.nao.org.uk/wp-content/uploads/2010/02/0910213.pdf (accessed 23 June 2019)

57. McCullough AL, Haycock JC, Forward DP, et al. II. Major trauma networks in England. *British Journal of Anaesthesia*. 2014; **113**: 202–6.

58. Celso B, Tepas J, Langland-Orban B, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. *Journal of Trauma and Acute Care Surgery* 2006; **60**: 371–8.

59. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. *New England Journal of Medicine* 2006; **354**: 366–78.

60. Lavoie A, Moore L, LeSage N, et al. The New Injury Severity Score: A More Accurate Predictor of In-Hospital Mortality than the Injury Severity Score. *The Journal of Trauma, Injury, Infection, and Critical Care*. 2004; 56: 1312–20.

61. Rees PSC. Pre-hospital Management of the Critically Injured Patient. In: *Trauma and Combat Critical Care in Clinical Practice* Ed. Hutchings S. 2016. Springer, Switzerland Pg 41-66.

62. Mercer S, Park C, Tarmey NT. Human factors in complex trauma. *BJA Education* 2015; 15: 231–6.

63. Mercer SJ, Kingston EV, Jones CPL. The trauma call. *British Journal of Medicine*. 2018; **361**: k2272–8.

64. Hodgetts TJ, Mahoney PF, Kirkman E. Damage control resuscitation. *Journal of the Royal Army Medical Corps*. 2007; 153: 299–300.

65. Flin R, Fioratou E, Frerk C, et al. Human factors in the development of complications of airway management: preliminary evaluation of an interview tool. *Anaesthesia*. 2013; **68**: 817–25.

66. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. *Best Practice & Research Clinical Anaesthesiology* 2011; **25**: 215–27.

67. Reid J. Speaking up: a professional imperative. *Journal of Perioperative Practice* 2013; **23**: 114–8.

68. Moneypenny MJ, Guha A, Mercer SJ, et al. Don't follow your leader: challenging erroneous decisions. *British Journal of Hospital Medicine*. 2013; **74**: 687–90.

69. Bromiley M, Mitchell L. Would you speak up if the consultant got it wrong?... and would you listen if someone said you'd got it wrong? *Journal of Perioperative Practice* 2009;**19**: 326.

70. Beament T, Mercer SJ. Speak up! Barriers to challenging erroneous decisions of seniors in anaesthesia. *Anaesthesia.* 2016; **71**: 1332–40.

71. Belyansky I, Martin TR, Prabhu AS. Poor Resident-Attending Intraoperative Communication May Compromise Patient Safety. *Journal of Surgical Research* 2011; **171**: 386–94.

72. Bould MD, Sutherland S, Sydor DT, et al. Residents' reluctance to challenge negative hierarchy in the operating room: a qualitative study. *Canadian Journal of Anaesthesia.* 2015; **62**: 576–86.

73. Friedman Z, Hayter MA, Everett TC, et al. Power and conflict: the effect of a superior's interpersonal behaviour on trainees' ability to challenge authority during a simulated airway emergency. *Anaesthesia* 2015; **70**: 1119–29.

74. Okuyama A, Wagner C, Bijnen B. Speaking up for patient safety by hospital-based health care professionals: a literature review. *BMC Health Services Research*. 2014; **14**: 61.

75. Kobayashi H, Pian-Smith M, Sato M, et al. A cross-cultural survey of residents' perceived barriers in questioning/challenging authority. *Quality and Safety in Health Care*. 2006; **15**: 277–83.

76. Pian-Smith MCM, Simon R, Minehart RD, et al. Teaching residents the two challenge rule: A simulation based approach to improve education and patient safety. *Simulation in Healthcare*. 2009; **71**: 110–1.

77. Weiss M, Kolbe M, Grote G, et al. Agency and Communion Predict Speaking Up in Acute Care Teams. *Small Group Research*. 2014; **45**: 290–313.

78. Pattni N, Arzola C, Malavade A, et al. Challenging authority and speaking up in the operating room environment: a narrative synthesis. *British Journal of Anaesthesia* 2019; **122**: 233-244

79. Bromiley M. Have you ever made a mistake? *Bulletin of the Royal College of Anaesthetists*. 2008; **48**: 2242–5.

80. Fonteyn ME, Kuipers B, Grobe SJ. A Description of Think Aloud Method and Protocol Analysis. *Qualitative Health Research*. 1993; **3**: 430–41.

81. Weller JM, Long JA. Creating a climate for speaking up. *British Journal of Anaesthesia*. 2019; 122: 710–3.

82. Bidwai A, Beament T, Anaesthesia SM, 2016. Hierarchy in critical airway management. Wiley Online Library

83. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. New England Journal of Medicine 2009; 360: 491–9.

84. Never Events list 2018. Available at: https://improvement.nhs.uk/documents/2266/Never_Events_list_2018_FINAL_v5.pdf (accessed 23 June 2019)

85. Van Klei WA, Hoff RG, Van Aarnhem E, et al. Effects of the introduction of the WHO "Surgical Safety Checklist" on in-hospital mortality: a cohort study. *Annals of Surgery*. 2012; **255**: 44–9.

86. Mercer SJ, Arul GS, Pugh HEJ, et al. Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma. *Journal of the Royal Army Medical Corps* 2014; **30**: 105–8.

87. Mercer SJ. Human Factors in Ballistic Trauma. In: *Trauma and Combat Critical Care in Clinical Practice* Ed. Hutchings S. 2016. Springer, Switzerland Pg 347–56.

88. Bowley DM, Barker P, Boffard KD. Damage control surgery-concepts and practice. *Journal of the Royal Army Medical Corps* 2000;146: 176–82.

89. Arul GS, Singh M, Ali AM, et al. Damage control surgery in neonates: Lessons learned from the battlefield. *Journal of Pediatric Surgery*. 2019 In Press (https://doi.org/10.1016/j.jpedsurg.2019.04.001).

90. Bricknell M, Hodgetts T, Beaton K, et al. Operation GRITROCK: the Defence Medical Services' story and emerging lessons from supporting the UK response to the Ebola crisis. *Journal of the Royal Army Medical Corps* 2016; 162:169–75.

91. Khan M. General surgical training for Operation Trenton. *Journal of the Royal Army Medical Corps* 2019 Published Online First: 20 February 2019. doi:10.1136/jramc-2018-001142

92. Arul GS, Pugh H, Kluth MJ, et al. Common goals, shared risk and a just culture: human factors lessons from the front line. *Journal of the Royal Society of Medicine*. 2017; 110: 93–7.

93. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *British Journal of Anaesthesia*. 2015; **115**: 827–48.

94. Mercer S, Whittle C, Siggers B, et al. Simulation, Human Factors and Defence Anaesthesia. *Journal of the Royal Army Medical Corps* 2010; **156(S4)**: S365–9.

95. Mercer SJ, Jones CP, Bridge M, et al. Systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma. *British Journal of Anaesthesia*. 2016; **117(S1)**: i49–i59.

96. Gleeson S, Groom P, Mercer S. Human factors in complex airway management. *BJA Education* 2016; **16**: 191-197

97. Hunt P. Lessons identified from the 2017 Manchester and London terrorism incidents. Part 1: introduction and the prehospital phase. *Journal of the Royal Army Medical Corps* Published Online First: 13 April 2018. doi: 10.1136/jramc-2018-000934

98. Smith J, Hodgetts T, Mahoney P, et al. Trauma governance in the UK defence medical services. *Journal of the Royal Army Medical Corps* 2007; **153**: 239–42.

99. Jagannathan S, Sighn N, Tong JL. Creating airway management guidelines for casualties with penetrating airway injuries. *Journal of the Royal Army Medical Corps*. 2011; **157**: 256.

100. Whittermore R, Chao A, Jang M, et al. Methods for knowledge synthesis: An overview. *Heart & Lung* 2014; **43**: 453–61.

101. Moynihan R. Evaluating health services: A reporter covers the science of research synthesis. 2004. Available at: https://www.milbank.org/wp-content/uploads/2016/04/Moynihan.pdf (accessed 23 June 2019)

102. Light R, Pillemer DB. Summing up. Harvard University Press Cambridge, MA; 1984.

103. World Health Organisation. WHO Guidelines for Safe Surgery 2009. Available at: https://apps.who.int/iris/bitstream/handle/10665/44185/9789241598552_eng.pdf;jsessionid=89FD1FA791EA66D6073556496858B192?sequence=1 (accessed 23 June 2019)

104. Fioratou E, Flin R, Glavin R. No simple fix for fixation errors: cognitive processes and their clinical applications. *Anaesthesia* 2010; **65**: 61–9.

105. Baxendale B, Sadler C. Creating a simulation strategy for the College. *Bulletin of the Royal College of Anaesthetists*. 2019; **111**: 33.

106. Fletcher G, Flin R, McGeorge P, Glavin R, et al. Rating non-technical skills: developing a behavioural marker system for use in anaesthesia. *Cognition, Technology & Work*. 2004; **6**: 165-171

107. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. *British Journal of Anaesthesia* 2010; **105**: 38–44.

108. Yule S, Flin R, Paterson-Brown S, et al. Development of a rating system for surgeons' non-technical skills. *Medical Education* 2006; **40**: 1098–104.

109. Cook TM, Andrade J, Bogod DG, et al. 5th National Audit Project (NAP5) on accidental awareness during general anaesthesia: patient experiences, human factors, sedation, consent, and medicolegal issues. *British Journal of Anaesthesia* 2014; **113**: 560–74.

110. Page MJ, Shamseer L, Tricco AC. Registration of systematic reviews in PROSPERO: 30,000 records and counting. *Systematic Reviews* 2018; 19: 1-9.

111. Breeze J, Gibbons AJ, Shieff C, et al. Combat-Related Craniofacial and Cervical Injuries: A 5-Year Review from the British Military. *The Journal of Trauma: Injury, Infection, and Critical Care.* 2011; **71**: 108–13.

112. Johnson-Laird P. What are Mental Models? Available at: https://mentalmodels.princeton.edu/about/what-are-mental-models/ (accessed 16 August 2019)

113. Mercer SJ, Lewis S, Wilson S, et al. Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries. *Journal of the Royal Army Medical Corps* 2010; **156(S1)**: S355–60.

114. Thomas A, Menon A, Boruff J, et al. Applications of social constructivist learning theories in knowledge translation for healthcare professionals: a scoping review. *Implementation Science* 2014; **9**: 54

115. Greaves I. Military Medicine in Iraq and Afghanistan: A Comprehensive Review. CRC Press; 2018.

116. Barrett M, Oborn E. Bridging the research-practice divide: Harnessing expertise collaboration in making a wider set of contributions. *Information and Organization* 2018; **28**: 44–51.

117. Kutner JS. A significant milestone for palliative care: imperative for dissemination and implementation research. *Journal of Palliative Medicine* 2011; **14**: 1194–5.

118. Cooksey D. A review of UK health research funding. The Stationery Office; 2006.

119. Davies H, Nutley S, Walter I. Why "knowledge transfer" is misconceived for applied social research. *Journal of Health Services Research & Policy* 2008; **13**: 188–90.

120. Grimshaw JM, Eccles MP, Lavis JN, et al. Knowledge translation of research findings. *Implementation Science* 2012; **7**: 2635–18.

121. Pentland D, Forsyth K, Maciver D, et al. Key characteristics of knowledge transfer and exchange in healthcare: integrative literature review. *Journal of Advanced Nursing* 2011; **67**: 1408–25.

122. Baumbusch JL, Kirkham SR, Khan KB, et al. Pursuing common agendas: a collaborative model for knowledge translation between research and practice in clinical settings. *Research in Nursing & Health* 2008; **31**: 130–40.

123. National Center for Dissemination of Disability Research. What is Knowledge Translation? Technical Brief Number 10. Available at: https://ktdrr.org/ktlibrary/articles_pubs/ncddrwork/focus/focus10/Focus10.pdf (accessed 23 June 2019)

124. Kiefer L, Frank J, Di Ruggiero E, et al. Fostering evidence-based decision-making in Canada: examining the need for a Canadian population and public health evidence centre and research network. *Canadian Journal of Public Health* 2005; **96**: I1–I19.

125. Mitton C, Adair CE, McKenzie E, et al. Knowledge transfer and exchange: review and synthesis of the literature. *The Milbank Quarterly*. 2007; **85**: 729–68.

126. Graham ID, Logan J, Harrison MB, et al. Lost in knowledge translation: Time for a map? *Journal of Continuing Education in the Health Professions* 2006; **26**: 13–24.

127. Mitton C, Adair CE, McKenzie E, et al. Designing a knowledge transfer and exchange strategy for the Alberta Depression Initiative: contributions of qualitative research with key stakeholders. *International Journal of Mental Health Systems* 2009; **3**: 11

128. Prihodova L, Guerin S, Tunney C, et al. Key components of knowledge transfer and exchange in health services research: Findings from a systematic scoping review. *Journal of Advanced Nursing*. 2018; **75**: 313–26.

129. Ho K, Bloch R, Gondocz T, et al. Technology-enabled knowledge translation: frameworks to promote research and practice. *Journal of Continuing Education in the Health Professions* 2004; **24**: 90–9.

130. Hemmelgarn BR, Manns BJ, Straus S, et al. Knowledge translation for nephrologists: strategies for improving the identification of patients with proteinuria. *Journal of Nephrology* 2012; **25**: 933–43.

131. Weaver AE, Thompson J, Lockey DJ. The effectiveness of a simple "Code Red" transfusion request policy initiated by pre-hospital physicians. *Scandinavian Journal of Trauma* 2012; **20**: 01

132. Hodgetts TJ. <c>ABC to ABC: redefining the military trauma paradigm. *Emergency Medicine Journal* 2006; **23**: 745–6.

133. Horne S, Smith JE. Preparation of the resuscitation room and patient reception. *Journal of the Royal Army Medical Corps*. 2011; **157(S1**): S267–72.

134. Midwinter MJ, Mercer S, Lambert AW. Making difficult decisions in major military trauma: a crew resource management perspective. *Journal of the Royal Army Medical Corps* 2011; **157**: S299-304

135. Ornato JP, Peberdy MA. Applying lessons from commercial aviation safety and operations to resuscitation. *Resuscitation* 2014; **85**: 173–6.

136. Inquiry under the fatal accidents and inquiries (Scotland) act 1976 into the sudden death of Gordon Ewing. Available at: https://www.scotcourts.gov.uk/search-judgments/judgment?id=328e86a6-8980-69d2-b500-ff0000d74aa7 (accessed 23 June 2019)

137. Mercer SJ, Whittle CL, Mahoney PF. Lessons from the battlefield: human factors in defence anaesthesia. *British Journal of Anaesthesia*. 2010; **105**: 9–20.

138. Hodgetts TJ, Davies S, Russell R, et al. Benchmarking the UK military deployed trauma system. *Journal of the Royal Army Medical Corps* 2007; **153**: 237–8.

139. Cook T, Woodall N, Frerk. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. *British Journal of Anaesthesia* 2011; **106**: 617-632

140. Defence Medical Group South West. *Operations and Contingency Handbook. SO3 Operations*. 2015.

141. Mercer SJ, Heames RM. Anaesthesia and critical care aspects of Role 2 Afloat. *Journal of the Royal Naval Medical Service*. 2013; **99**: 140–3.

142. McCallum JS. Followership: the other side of leadership. *Ivey Business Journal Online* 2013 Oct 14; 1–3.

143. Bligh MC, Kohles JC. From Radical to Mainstream? *Zeitschrift für Psychologie*. 2012; **220**: 205–9.

144. Whitlock J. The value of active followership. *Journal of Nursing Management* 2013; **20**: 20–3.

145. Townsend P, Gebhartd JE. For service to work right, skilled leaders need skills in "followership". *Managing Service Quality*. 1997; **7**: 136–40.

146. Chaleff I. Creating New Ways of Followership. In: Riggio RE, Chaleff I, Lipman-Blumen J, editors. The Art of Followership: How Great Followers Create Great Leaders and Organisations. Wiley; 2008: 67–88.

147. Chaleff I. The Courageous Follower. 3rd ed. San Francisco: Berrett-Koehler; 2009.

148. Kelley RE. The Power of Followership. New York: Doubleday; 1992.

149. Kellerman B. Followership: How Followers Are Creating Change and Changing Leaders. Boston: Harper Business; 2008.

150. Kelley RE. Rethinking Followership. In: RE R, Chaleff I, Lipman-Blumen J, editors. The Art of Followership - How Great Followers Create Great Leaders and Organisations. 1st ed. San Francisco: Wiley; 2008. pp. 5–16.

151. Grint K, Holt C. Followership in the NHS. London, UK: King's Fund. 2011. Available at: http://www.wtsinternational.org/assets/65/7/Followership_in_the_NHS-2.pdf (accessed 23 June 20190

152. Tarrant C, Leslie M, Bion J, et al. A qualitative study of speaking out about patient safety concerns in intensive care units. *Social Science & Medicine*. 2017; **193**: 8-15.

153. Guris RD, Duarte SS, Miller CR, et al. Training novice anaesthesiology trainees to speak up for patient safety. British Journal of Anaesthesia 2019; **122**: 767-775

154. Kuduvalli PM, Parker CJ, Leuwer M, et al. Retention and transferability of team resource management skills in anaesthetic emergencies: the long-term impact of a high-fidelity simulation-based course. *European Journal of Anaesthesiology* 2009; **26**: 17–22.

155. NHS Improvement. The NHS Patient Safety Strategy. 2019 Available at: https://improvement.nhs.uk/resources/patient-safety-strategy/ (accessed 11 October 2019)

156. Jeyanathan J, O'Brien D, Smith JE. Intensive care medicine on military operations in the resource-limited environment: a case series. *BMJ Military Health.* Published Online First: 02 March 2020. doi: 10.1136/jramc-2019-001344

Appendix 1
Full Publication List – Dr Simon Mercer

Year	Publication	Type
2020	**The anaesthetic management of the airway after blunt and penetrating neck injury.** Owston H, Jones C, Groom P and **MERCER SJ**. *Trauma* (*Inpress*) DOI: 10.1177/1460408619886216	Journal Article
2019	**Designing and implementing a bespoke multidisciplinary paediatric emergency refresher course in an adult tertiary hospital.** Miller T, Grice J, Wharton T, **MERCER SJ**. *BMJ Simulation and Technology Enhanced Learning* 2019; 5(S2): A60	Conference Abstract
2019	Trialling a high-fidelity simulation course on the management of general surgical emergencies. Bagchi A, Parr T, Shanahan T, **MERCER SJ** *BMJ Simulation and Technology Enhanced Learning* 2019; 5(S2): A60	Conference Abstract
2019	**Education Training and Human Factors.** **MERCER SJ**, Khan M, Matthews JJ, Reavley P, Gurney I, Glover N, Jones CP **Military Medicine in Iraq and Afghanistan. A Comprehensive Review. Edited by Ian Greaves. 2019 Chapter 22: 485-509, CRC Press, Boca Raton, FL**	Book Chapter
2019	**A service evaluation of silver trauma in a North West England major trauma centre** Kennett A, **MERCER S** and Cromer D. *Anaesthesia* 2019; **74(S2):** 27	Conference Abstract
2019	**Silver Trauma in a Major Trauma Centre - A Service Review for 2017** Kennett A, Cromer D, **MERCER SJ** *EC Anaesthesia* 2019; **53**; 65-68.	Journal Article
2019	**Team-working, communication and use of communication aids and checklists (Book Chapter)** **MERCER SJ** Accepted: Chapter in *Section 2 - The impact of human factors in clinical practice in Decision-Making and Simulation in Obstetric Anaesthesia. Cambridge University Press.* 2019 Chapter 8 Pg 45-51	Book Chapter
2019	**Followership in complex trauma** Fadden S, **MERCER SJ** *Trauma* 2019; **21**: 6-13	Journal Article
2018	**O18 Follow the file: using a major incident simulation to train undergraduates in complex trauma management** Fawkner-Corbett J, Jones CPL, **MERCER SJ** *BMJ Simulation and Technology Enhanced Learning* 2018; 4 (S2): A8-A9	Conference Abstract
2018	**A systematic review of 3251 emergency department thoracotomies: is it time for a national database?** Nevins EJ, Bird NTE, Malik HZ, **MERCER SJ**, Shahzad K, Lunevicius R, Taylor JV, Misra N. *European Journal of Trauma and Emergency Surgery* 2018; doi.org/10.1007/s00068-018-0982-z	Journal Article
2018	**The Trauma Call** **MERCER SJ**, Kingston EV, Jones CPL *British Medical Journal* 2018; **361**: 410-413	Journal Article
2018	**Simulating high-fidelity emergency front-of- neck access with a novel part-task trainer** Berwick RJ, **MERCER SJ**, Groom P *British Journal of Anaesthesia* 2018; **121**: e2	Journal Article Original Research
2018	**Analysis of 'Code red trauma calls' promoting the development of a novel cognitive aid for blood product resuscitation.** Morrton S, Perritt E, Gorry J, Jones CPL, **MERCER SJ.** *Journal of Clinical Investigation and Studies* 2018; **1**: 1-7	Journal Article

2018	**Human Factors in Preventing Complications in Anaesthesia** Jones CP, Fawker-Corbett J, Groom P, Morton B, Lister C, **MERCER SJ.** *Anaesthesia* 2018; **73**(S1): 12-24	Journal Article
2017	**Using full immersive simulation to prepare trauma teams to work in a major trauma centre** **MERCER SJ** *Trauma* 2017: **19**: 277-285	Journal Article
2017	**Effect of expertise on diagnosis accuracy, non-technical skills and thought processes during simulated high-fidelity anaesthetist scenarios** McRobert AP, **MERCER SJ,** Raw D, Goulding J, Williams MA *BMJ Simulation & Technology Enhanced Learning* 2017:**3**;43-47	Journal Article Original Research
2017	**Human Factors in Ballistic Trauma** **MERCER SJ in Ballistic Trauma. A Practical Guide. Fourth Edition.** Editors Breeze MJ, Penn-Barwell JG, Keene D, O'Reilly D, Jeyanathan J, Mahoney PF. Chapter 22. Pg 347-356. Springer, 2017	Book Chapter
2017	**Military Anaesthesia in Contingencies: What Skill Sets Are Required and How Will We Prepare Our Trainees?** **MERCER SJ**, Jones CP, Round J, Parkhouse D. *Journal of the Royal Army Medical Corps* 2017: **163**;226-232	Journal Article
2017	**Human Factors on Contingency Operations** **MERCER SJ**, Khan M, Scott T, Matthews J, Henning D, Stapley S *Journal of the Royal Army Medical Corps* 2017: **163**; 78-83	Journal Article
2017	**Military Anaesthesia** (Chapter 78) Mahoney PF, Kirkman E, Watts S, Smyth K, Nordmann G, Tarmey NT, **MERCER SJ**, Woolley T, Aldington D, Turner S, Charlotte Small C, and Wood P *The Oxford Textbook of Anaesthesia* (27 April 2017) ISBM-10: 0199642044	Book Chapter
2017	**Establishing and Maintaining a Robust Role 2 Afloat Organization Within the Royal Naval Medical Services.** Matthews JJ, **MERCER SJ**, Khan MA, Hillman CM, Robin J, Scott TE. *Journal of the Royal Navy Medical Services* 2017; **103**: 10-13	Journal Article
2017	**The Role 2 Afloat Custodian** Hudson J, **MERCER SJ**. *Journal of the Royal Navy Medical Services* 2017; **103**: 14-16	Journal Article
2017	**The Maritime Medical Emergency Response Team: What do we really need?** **MERCER SJ**, Scott TE, Khan MA, Hillman CM, Robin J Matthews JJ. *Journal of the Royal Navy Medical Services* 2017; **103**: 17-20	Journal Article
2017	**Consideration of The Medical Care and Biomedical Support of Women and Children on Role 2 Afloat Maritime Contingency Operations** Hillman CM, Horrobin R, Mills S, **MERCER SJ**. *Journal of the Royal Navy Medical Services* 2017; **103**: 21-25	Journal Article
2017	**Hybrid High Fidelity Military Simulation** Fadden SJ, Jones CP, Round JA, **MERCER SJ.** *BMJ Journal of Simulation Technology and Enhanced Learning* 2017; **2(S1):** A63	Conference Abstract
2017	**The Role of the Operating Department Practitioner on Board Role 2 Afloat** Stables A, Seal G, **MERCER SJ** *Journal of the Royal Navy Medical Services* 2017; **103**: 30-31	Journal Article
2016	**Speak Up! Barriers to Challenging Erroneous Decisions of Seniors in Anaesthesia** Beament T, **MERCER SJ** *Anaesthesia* 2016; **71**: 1332–1340	Journal Article Original Research
2016	**The trauma team and initial management of the critically injured patient** (Chapter 4) In: *Trauma and Combat Critical Care in Clinical Practice* Ed. Hutchings S **MERCER SJ** Springer; 1st Edition (10 October 2016)	Book Chapter
2016	**A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma.** **MERCER SJ**, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P *British Journal of Anaesthesia* 2016: **117 (S1):** i49–i59	Journal Article

2016	**Human Factors in Complex Airway** Gleeson S, Groom P, **MERCER SJ** *British Journal of Anaesthesia Education* 2016; **16**: 191-197	Journal Article
2016	**Don't Follow your leader: challenging erroneous decision.** Chapter 14 Moneypenny M, Guha A, **MERCER SJ**, O'Sullivan H and McKimm J Clinical Leadership Made Easy Integrating Theory and Practice. Quay Books, London, 2016	Journal Article Original Research
2016	**Shaping Military Training in the Era of Contingency and Revalidation** Jones CJ, **MERCER SJ**, Mahoney PF *Bulletin of the Royal College of Anaesthetists* 2016: **97**: 41-43	Journal Article
2016	**Organising In-Situ Simulation - One Trainee's Description of a Valuable Learning Opportunity** Huddlestone E, **MERCER SJ** *Bulletin of the Royal College of Anaesthetists* 2016; **95**: 28-30	Journal Article
2016	**Piloting a fully immersive in-situ simulation teaching course for final year medical students: 'carry the bleep'.** Yiangou A, Kamalanathan S, Altemimi B, **MERCER SJ.** *BMJ Journal of Simulation Technology and Enhanced Learning* 2016; **2(S1):** A27	Conference Abstract
2016	**Fully immersive simulation improves confidence when dealing with a tracheostomy emergency in junior medical and nursing staff.** Taylor J, **MERCER SJ** *European Journal of Anaesthesiology* 2016; 33(**eS54**): 486	Conference Abstract
2016	**Does attending an advanced life support course as a final year medical student improve key non-technical skills during CPR?** Taylor J, **MERCER SJ** *European Journal of Anaesthesiology* 2016; 33(**eS54**): 415	Conference Abstract
2016	**Speak up! How do we challenge consultants when they can't intubate?** Bidwai A, Beament T, **MERCER S** *British Journal of Anaesthesia* 2016: **117**(S1); i111-i112	Conference Abstract
2016	**Central neuraxial blockade and anticoagulants in four minutes: aiming to improve anaesthetists knowledge of new oral anticoagulants and central neuraxial blockade** Bordoni J, **MERCER S** *Anaesthesia* 2016; **71**(S2): 13	Conference Abstract
2016	**Challenging consultants: how can junior anaesthetic trainees learn how to effectively challenge?** Bidwai A, Beament T, **MERCER S** *Anaesthesia* 2016; **71**(S2): 60	Conference Abstract
2016	**Training for Damage Control Resuscitation using a Rapid Infuser** **MERCER SJ**, Seal G, Stables A *Journal of the Royal Army Medical Corps* doi:10.1136/jramc-2016-000711	Journal Correspondence
2016	**Reply to: the use of advanced airway management devices in clinical practice.** Batuwitage B, Nishikawa K, **MERCER S**, McDonald A, Charters P. *European Journal of Anaesthesiology*. 2016 Feb 16.	Journal Correspondence
2015	**Hierarchy in critical airway management** Bidwai A, Beament T **MERCER S** *Anaesthesia* 2015; **71**: 110–111	Journal Correspondence
2015	**Ongoing military evolution of Trauma Life Support** **MERCER SJ**, Mahoney PF *Anaesthesia* 2015: **70**; 1320–1333	Journal Correspondence
2015	**The chewing gum controversy-time for a consensus?** Jain N, **MERCER SJ.** *Journal of Clinical Anesthesia* 06/2015; DOI:10.1016/j.jclinane.2015.05.009	Journal Correspondence
2015	**What do we need for airway management of Adult Casualties on The Primary Casualty Receiving Ship? A Review of airway management on Role 3 Afloat** **MERCER SJ**, Read J, Sudheer S, Risdall JE, Connor D *Journal of the Royal Navy Medical Services* 2015; **101**: 155-158	Journal Article
2015	**Practical Anaesthesia** (Chapter)	Book Chapter

	Ross N, Arumugakani G, Wood P, Thomas R, Dawes R, **MERCER S**, Jagdish S, Bodenham A, Bunker N, Saddler J, Myles P *Oxford Handbook of Anaesthesia* Dec 2015: 977-1038	
2015	**Human Factors in Decision Making in Major Trauma in Camp Bastion, Afghanistan.** Arul S, Pugh H, **MERCER SJ**, Midwinter M *Annals of The Royal College of Surgeons of England* 2015*;* **97**: 262-268	Journal Article Original Research
2015	**Human Factors in Trauma** **MERCER SJ**, Tarmey N, Park C *BJA Education* 2015; **15**: 231-236	Journal Article
2015	**Preparing the Team** (Chapter 2) **MERCER S**, Frazer RS, Via D *Combat Anesthesia: The First 24 Hours* (2015): 31-40, *Borden Institute Fort Sam Houston, Texas*	Book Chapter
2015	**Managing the Airway** (Chapter 6) **MERCER S**, Breeze J Combat Anesthesia: *The First 24 hours* (2015): 75-83, *Borden Institute Fort Sam Houston, Texas*	Book Chapter
2015	**Comparison between bougies and stylets for intubation with the C-MAC D-Blade videolaryngoscope.** Batuwitage B, McDonald A, Nishikawa K, Lythgoe D, **MERCER SJ**, Charters P. *European Journal of Anaesthesia* 2015; **32**: 400-405	Journal Article Original Research
2015	**Using Fully Immersive Simulation to Train Defence Anaesthetists for Contingency Operations** Jones C, Hunt D, Clitheroe E, Round J, **MERCER SJ**. *BMJ Journal of Simulation Technology and Enhanced Learning* 2015; **1(S2):** A44 10.1136/bmjstel-2015-000075.109	Conference Abstract
2015	**Using 'In Situ Simulation' To Identify Latent Errors in General Practice: A Pilot Study** Welfare E, **MERCER S**. *BMJ Journal of Simulation Technology and Enhanced Learning* 2015; **1(S2):** A44 10.1136/bmjstel-2015-000075.133	Conference Abstract
2015	**Reviewing the Impact of a One-Day Fully Immersive Simulation Faculty Development Course** Bidwai A, **MERCER SJ** *BMJ Journal of Simulation Technology and Enhanced Learning* 2015; **1(S2):** A54 10.1136/bmjstel-2015-000075.132	Conference Abstract
2015	**Using Fully Immersive Simulation to Identify Latent Errors in a New Major Trauma Unit Centre** Jones C, Murphy M, Rimmer R, Welfare E, **MERCER S** *BMJ Journal of Simulation Technology and Enhanced Learning* 2015; **1(S2):** A21 10.1136/bmjstel-2015-000075.52	Conference Abstract
2014	**Speak Up! What are the Barriers to Challenging Seniors?** Beament T, **MERCER S**. *BMJ Journal of Simulation Technology and Enhanced Learning* 2014; **99(**Suppl 1): A2 [10.1136/bmjstel-2014-ASPiH_abstract.50]	Conference Abstract
2014	**Investing Latent Errors in the Operating Theatre Using High Fidelity Simulation** Welfare E, Lacasia-Purroy C, Groom P, **MERCER S.** *BMJ Journal of Simulation Technology and Enhanced Learning* 2014; **99**(Suppl 1): A67-68 [10.1136/bmjstel-2014-ASPiH_abstract.163]	Conference Abstract
2014	**Performance Improvement Through Best Practice Team Management – Human Factors in Complex Trauma** **MERCER SJ**, Arul S, Pugh H, Midwinter MJ *Journal of the Royal Army Medical Corps* 2014; **160**: 105-108	Journal Article
2013	**Anaesthesia and Critical Care Aspects of Role 2 Afloat** **MERCER SJ**, Heames RM *Journal of the Royal Navy Medical Services* 2013: **99**: 141-143	Journal Article
2013	**Don't follow your leader: challenging erroneous decisions** Moneypenny MJ, Guha A, **MERCER SJ**, O'Sullivan H, McKimm J	Journal Article

	British Journal of Hospital Medicine 2013; **74**: 687-690	
2013	**The P-POSSUM scoring systems for predicting the mortality of neurosurgical patients undergoing craniotomy: Further validation of usefulness and application across healthcare systems** **MERCER SJ**, Guha A, Ramesh VJ *Indian Journal of Anaesthesia* 2013; **57**: 587-591	Journal Article Original Research
2013	**Training and Revalidation in Defence Anaesthesia** **MERCER SJ** *Bulletin of the Royal College of Anaesthetists* 2013; **80**: 16-18	Journal Article
2013	**Collecting Swimming Badges: Key Components of the Curriculum Vitae (CV) for Consultant Shortlisting** Kingston EV, **MERCER SJ** *Anaesthesia* 2013: **69(S2)**; 49	Conference Abstract
2013	**A Service Evaluation on the Use and Interpretation of RoTEM™ Six Months After its Introduction in a Regional Trauma Centre** Clarke T, Batuwitage B and **MERCER S** *Anaesthesia* 2013: **68**; 993	Conference Abstract
2013	**Determining the best introducer for intubating with the C-MAC™ D-blade videolaryngoscope** Batuwitage B, McDonald A, Nishikawa K, Lythgoe D, **MERCER S** and Charters P *British Journal of Anaesthesia* 2013; **110**: 883P	Journal Correspondence
2013	**Implementation of New Tracheal Extubation Guidelines** Bidwai A and **MERCER S** *Anaesthesia* 2013; **68**: 659	Conference Abstract
2013	**Haemorrhage and Coagulopathy in the Defence Medical Services** **MERCER SJ**, Tarmey NT, Woolley T, Wood P, Mahoney PF *Anaesthesia* 2013: **68** (S1); 49–60	Journal Article
2013	**Military Experience of Human Factors in Airway Complications** **MERCER SJ,** Tarmey N, Mahoney PF *Anaesthesia* 2013; **68**: 1081-1082	Journal Correspondence
2012	**Medical Simulation 'In My World'** **MERCER SJ** *Anaesthesia* 2012; **67**: 1177	Journal Correspondence
2012	**Simulation in-situ** **MERCER SJ,** Wimlett S *Bulletin of the Royal College of Anaesthetists* 2012; **76**: 28-30	Journal Article
2012	**Optimising Communication in Damage Control Resuscitation – Damage Control Surgery Sequence (DCR-DCS) in Major Trauma Management** Arul GS, Pugh HEJ, **MERCER SJ,** Midwinter MJ *Journal of the Royal Army Medical Corps* 2012; **158**: 82-84	Journal Article
2012	**An Audit of the Peri-operative Care of High-Risk Surgical Patients** Palmer D, Oates J and **MERCER S** *Anaesthesia* 2012: **67**; 1297	Conference Abstract
2012	**What should be included in a simulation course for anaesthetists? The Merseyside trainee perspective.** **MERCER SJ,** Moneypenny MJ, Fredy O, Guha A *European Journal of Anaesthesiology* 2012: **29**; 137-142	Journal Article Original Research
2011	**Making difficult decisions in major military trauma: A Crew Resource Management Perspective** Midwinter M, **MERCER SJ,** Lambert AW**,** de Rond M. *Journal of Royal Army Medical Corps* 2011: **157**; S299-S304	Journal Article
2011	**Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries** **MERCER SJ,** Lewis SE, Wilson SJ, Groom P. *Journal of the Royal Army Medical Corps* 2011; **157**: 257	Journal Article Original Research
2011	**Can Sugammadex Save a Patient in a Simulated 'Cannot Intubate, Cannot Ventilate' Situation?** **MERCER SJ**, Moneypenny MJ *Anaesthesia* 2011; **66**: 223–224	Journal Correspondence

2010	**Trainee Anaesthetists' Attitudes to Error, Safety and the Law** **MERCER SJ**, Moneypenny MJ, Guha A *European Journal of Anaesthesia* 2010; **27**: 396	Journal Correspondence
2010	**Simulation, Human Factors and Defence Anaesthesia** **MERCER SJ,** Siggers B, Whittle CL *Journal of the Royal Army Medical Corps* 2010; **156**: S367-374	Journal Article
2010	**Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries** **MERCER SJ,** Lewis SE, Wilson SJ, Groom P, Mahoney PF. *Journal of the Royal Army Medical Corps* 2010; **156**: S357-362	Journal Correspondence
2010	**Whose Room Is It Anyway?** **MERCER SJ**, Moneypenny MJ, Raw D *Bulletin of the Royal College of Anaesthetists* 2010; **64**: 49-51	Journal Article
2010	**Simulation training for the Frontline- realistic preparation for Role 1 doctors** **MERCER SJ**, Howell M, Simpson R *Journal of the Royal Army Medical Corps* 2010; **156**: 87-89	Journal Article
2010	**Lessons from the Battlefield: Human Factors in Defence Anaesthesia** **MERCER SJ**, Whittle CL, Mahoney PF *British Journal of Anaesthesia* 2010 **105**: 9-20	Journal Article
2010	**Assessing the Implementation of Guidelines for the Management of the Potentially Injured Cervical Spine in Unconscious Trauma Patients in England** **MERCER SJ,** Guha A *Journal of Trauma, Injury and Infection and Critical Care* 2010: **68**: 1445-1550	Journal Article
2010	**Does the Tri-Service anaesthetic apparatus still have a role in modern conflict?** **MERCER SJ,** Beard DJ *Bulletin of the Royal College of Anaesthetists* 2010: **60**; 18-20	Journal Article
2010	**A Clinical Fellowship in Simulation in Healthcare** **MERCER SJ**, Jones N, Guha A *BMJ Careers*. 13 February 2010; 52-54	Journal Article
2010	**Simulation in Defence Anaesthesia** **MERCER SJ**, Frazer RS *Journal of the Royal Army Medical Corps* 2010; **156**: 60	Conference Abstract
2010	**Testing adherence to the DAS Algorithm for Difficult Tracheal Intubation During Rapid Sequence Induction of Anaesthesia.** **MERCER SJ**, Guha A *Anaesthesia* 2010; **65**: 426	Conference Abstract
2009	**Listening to the End-User: Designing a Simulation Course for Senior Trainees in Anaesthesia in the United Kingdom** **MERCER SJ**, Moneypenny MJ, Guha A *Simulation in Healthcare* 2009; **4**: 274	Conference Abstract
2009	**A United Kingdom Evaluation of POSSUM and P-POSSUM Scoring Systems for Predicting the Mortality of Neurosurgical Patients Undergoing Craniotomy** **MERCER SJ**, Ramesh VJ, A Guha *Journal of Neurosurgical Anesthesiology* 2009: **21**: 276-277	Conference Abstract
2009	**Components of the Curriculum Vitae Important for Short Listing – a Survey of Newly Appointed Consultant Anaesthetists** **MERCER SJ** *Anaesthesia* 2009; **64**: 342–343	Conference Abstract
2009	**The Early Detection and Management of Neuropathic Pain Following Combat Injury** **MERCER SJ**, Chavan, Tong JL, Connor DJ, de Mello WF *Journal of the Royal Army Medical Corps* 2009; **155**: 94-98	Journal Article
2009	**'The Drug of War' – A Historical Review of the Use of Ketamine in Military Conflicts** **MERCER SJ** *Journal of Royal Naval Medical Services* 2009; **95**: 145-150	Journal Article

2009	**Simulation and Training in Anaesthesia** Guha A, Moneypenny MJ, **MERCER SJ** *British Journal of Anaesthesia* 2009; **103**: 770	Journal Correspondence
2009	**Communication and Simulation for Anaesthetists.** **MERCER SJ**, Moneypenny MJ, Guha A. *Anaesthesia* 2009: **64**; 1259-60	Journal Correspondence
2009	**Minimally Invasive Total Knee Arthroplasty for Osteoarthritis.** Moneypenny MJ. **MERCER SJ** *New England Journal of Medicine* 2009: **361**; 633	Journal Correspondence
2008	**A National Survey into the Peri-operative Anaesthetic Management of Patients Presenting for Surgical Correction of a Fractured Neck of Femur** **MERCER SJ,** Cheater L *Anaesthesia* 2008: **63**; 1015	Journal Correspondence
2008	**Anaesthesia in the Armed Forces – A History of The Triservice Apparatus.** **MERCER SJ** *Journal of the Royal Navy Medical Service* 2008; **94.2:**74-82	Journal Article
2008	**Inadvertent Intra-arterial Injection During Cardio-Pulmonary Resuscitation** **MERCER SJ** *Journal of the Royal Army Medical Corps* 2008; **154: 192**	Conference Abstract
2008	**Is it Practical to Have a Cell Saver in the Maternity Theatre in a District General Hospital?** **MERCER SJ** *International Journal of Obstetric Anesthesia* 2008: **17**; S48	Conference Abstract
2001	**Randomized clinical trial intravenous fluid replacement during bowel preparation for surgery** Sanders G, **MERCER SJ**, Saeb-Parsey K, Akhavani MA, Hosie KB, Lambert AW *British Journal of Surgery* 2001; **88**: 1363-5.	Journal Article Original Research
2001	**Intravenous Fluid Minimises the Adverse Effects of Picolax Bowel Preparation** Sanders G, **MERCER SJ**, Saeb-Parsey K, Akhavani MA, Hosie KB, Lambert AW *European Journal of Surgical Oncology* 2001; **27:** 779	Conference Abstract
2001	**Is Intravenous Fluid Replacement Indicated During Bowel Preparation for Colonic Surgery?** Sanders G, **MERCER SJ**, Saeb-Parsey K, Akhavani MA, Hosie KB, Lambert AW *British Journal of Surgery - Supplement.* 88 Supplement 1:52, May 2001.	Conference Abstract

PROSPERO
International prospective register of systematic reviews

NHS National Institute for Health Research

Airway trauma management: a systematic review

Omar Al-Mukhtar, Ben Morton, Simon Mercer, Ed Clitheroe, Peter Groom, Matthew Bridge, Clinton Jones

Citation

Omar Al-Mukhtar, Ben Morton, Simon Mercer, Ed Clitheroe, Peter Groom, Matthew Bridge, Clinton Jones. Airway trauma management: a systematic review. PROSPERO 2016 CRD42016032763
Available from: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42016032763

Review question

To conduct a narrative review to determine the evidence base for airway trauma management.

Searches

The databases Embase and MEDLINE will be searched.
The search will be restricted to articles published in the English language on or after the year 2000.
Additional details of the search strategy can be found in the attached PDF document.

Search strategy

http://www.crd.york.ac.uk/PROSPEROFILES/32763_STRATEGY_20151131.pdf

Types of study to be included

There are no restrictions on the types of study design eligible for inclusion.

Condition or domain being studied

Airway trauma (blunt, burns, penetrating, blast, miscellaneous).

Participants/population

Inclusion criteria:
Adults >18 with airway trauma.
Exclusion criteria:
Published before 2000, children, non-human.

Intervention(s), exposure(s)

Inclusion critieria:
Paper published on or after 2000 (contemporary practice).
Paper reports airway trauma (blunt, burns, penetrating, blast or miscellaneous) and anaesthetic managment.
Exclusion criteria:
Children (<18).
Animal studies.
Does not deal with acute trauma.
Does not deal with airway trauma.
Does not have an airway management focus.

Comparator(s)/control

Not applicable.

Context

Airway trauma is an acutely life threatening condition that anaesthetists must manage in emergency settings with little or no preparation time to preserve life.
We will employ a broad-based search strategy to review and describe best evidenced-based practice for patients who present with airway trauma to guide anaesthetic practice.

Main outcome(s)

Safe and effective management of airway trauma caused by blunt, burns, penetrating or blast injury.

Timing and effect measures

We will examine the speed of intervention and reported patient outcomes.

Additional outcome(s)
None.

Data extraction (selection and coding)
Two independent reviewers will check titles and abstracts from the search results. Papers will be categorised into include or exclude by reviewers, and will be reviewed if they recieve one or more 'include' from the two reviewers. Papers will be fully reviewed for inclusion in the absence of two or more clear decisions to exclude the article. An a priori data collection database will be created to incorporate the data of interest. Papers will be allocated to the two independent reviewers who will then extract the data using the a priori database. Their results will be compared, with any discrepancies prompting a re-examination of the article in question. Any continued disagreement at this stage will be arbitrated by a third independent reviewer. Authors will be contacted to clarify the outcome data if it is unclear in the paper.
Data extraction: study type, number of patients, mechanism of injury, injuries, airway injury, airway issues, management technique, procedure success, recourse to surgical airway, patient physiology, patient outcome.

Risk of bias (quality) assessment
We will use the Jadad scale to independently assess the methodological quality of the clinical trials.

Strategy for data synthesis
We will collect aggregated data and perform a narrative synthesis.

Analysis of subgroups or subsets
None planned.

Contact details for further information
Ben Morton
ben.morton@lstmed.ac.uk

Organisational affiliation of the review
None

Review team members and their organisational affiliations
Dr Omar Al-Mukhtar. Western Health
Dr Ben Morton. Aintree University Hospital
Dr Simon Mercer. Aintree University Hospital
Dr Ed Clitheroe. Aintree University Hospital
Dr Peter Groom. Aintree University Hospital
Dr Matthew Bridge. Aintree University Hospital
Dr Clinton Jones. Aintree University Hospital

Anticipated or actual start date
01 December 2015

Anticipated completion date
01 March 2016

Funding sources/sponsors
None

Conflicts of interest
None known

Language
English

Country

England

Stage of review
Review_Completed_published

Details of final report/publication(s)
S. J. Mercer, C. P. Jones, M. Bridge, E. Clitheroe, B. Morton, P. Groom; Systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma, BJA: British Journal of Anaesthesia, Volume 117, Issue suppl_1, 1 September 2016, Pages i49–i59,

https://doi.org/10.1093/bja/aew193
https://www.ncbi.nlm.nih.gov/PubMed/27566791

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Airway Management; Anesthetics; Anesthetics, General; Humans; Intubation; Respiration Disorders; Respiratory System

Date of registration in PROSPERO
31 December 2015

Date of publication of this version
10 January 2018

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Versions
31 December 2015
10 January 2018

Human factors in preventing complications in anaesthesia

Ben Morton, Simon Mercer, Clinton Jones, Joanna Fawker-Corbett, Claire Lister, Peter Groom

Citation

Ben Morton, Simon Mercer, Clinton Jones, Joanna Fawker-Corbett, Claire Lister, Peter Groom. Human factors in preventing complications in anaesthesia. PROSPERO 2017 CRD42017060872 Available from: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42017060872

Review question

How does human factors research reduce complications in anaesthesia

Searches

We searched MEDLINE and CINAHL for papers reporting on human factors and non-technical skills in anaesthesia. We limited the search to articles published from the year 2000 onwards to represent contemporary practice. The search included full text reports of articles from peer-reviewed journals published in English and there were no restrictions to the studies reviewed. We also manually searched the following anaesthetic journals by typing ‘human factors’ into the search box for Anaesthesia, Anesthesiology, Anesthesia & Analgesia, The British Journal of Anaesthesia, the Canadian Journal of Anaesthesia and European Journal of Anesthesiology accepting articles (not abstracts presented at conferences) from >2000. In addition, reference lists of the articles reviewed were scrutinized for additional relevant articles and book chapters.

Types of study to be included

No restriction on types of study design eligible for inclusion

Condition or domain being studied

In this review we examine how the implementation of human factors research impacts on safe delivery of anaesthesia for patients

Participants/population

Humans undergoing anaesthesia (no age restriction)

Intervention(s), exposure(s)

Inclusion criteria were papers referring to human factors, non-technical skills, team resource management or crew resource management, papers published on or after 2000.
The exclusion criteria were animal studies, papers not referring to human factors, non-technical skills, team resource management or crew resource management in theatres, anaesthesia, trauma or critical care.

Comparator(s)/control

Not applicable.

Context

Main outcome(s)

Anaesthesia safety

Additional outcome(s)

Application of human factors in clincial settings :
Teamwork
Task completion
Equipment use
Workspace environment and culture
Organisational impacts

Data extraction (selection and coding)

Titles and abstracts of the references obtained were reviewed by two independent reviewers. Articles were

categorized as for inclusion or exclusion. Articles were removed if both reviewers agreed independently to exclude. In the event of agreement to include or a discordant opinion, articles were reviewed in full by a third, independent reviewer.

Risk of bias (quality) assessment
As this review will not restrict study design inclusion, we will not perform a risk of bias assessment as part of the systematic review

Strategy for data synthesis
Descriptive synthesis

Analysis of subgroups or subsets
None planned

Contact details for further information
Dr Morton
ben.morton@lstmed.ac.uk

Organisational affiliation of the review
None

Review team members and their organisational affiliations
Dr Ben Morton. Aintree University Hospital NHS Foundation Trust
Dr Simon Mercer. Aintree University Hospital NHS Foundation Trust
Dr Clinton Jones. Aintree University Hospital NHS Foundation Trust
Dr Joanna Fawker-Corbett. Aintree University Hospital NHS Foundation Trust
Dr Claire Lister. Aintree University Hospital NHS Foundation Trust
Dr Peter Groom. Aintree University Hospital NHS Foundation Trust

Anticipated or actual start date
01 March 2017

Anticipated completion date
01 June 2017

Funding sources/sponsors
None

Conflicts of interest
None known

Language
English

Country
England

Stage of review
Review_Completed_published

Details of final report/publication(s)
Jones, C. P. L., Fawker-Corbett, J., Groom, P., Morton, B., Lister, C. and Mercer, S. J. (2018), Human factors in preventing complications in anaesthesia: a systematic review. Anaesthesia, 73: 12–24. doi:10.1111/anae.14136
https://www.ncbi.nlm.nih.gov/PubMed/29313908
DOI: 10.1111/anae.14136

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Anesthesia; Anesthesiology; Humans

Date of registration in PROSPERO
03 April 2017

Date of publication of this version
22 January 2018

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Versions
03 April 2017
22 January 2018

Appendix 3
Summary of Tables

Appendix 4
Summary of Figures